For JEE & Other Engineering Entrance Examinations

CHEMISTRY MCQ

MULTIPLE-CHOICE-QUESTION BANK

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BHARATI BHAWAN (P & D)

Chemistry MCQ

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Preface

This book is meant for the IIT-JEE and other examinations in which multiple-choice questions are asked. The book is divided into five parts. The first three parts cover physical, inorganic and organic chemistry, topicwise. In each of these parts a chapter is devoted to assertion–reason questions. In the fourth part miscellaneous questions have been given. In the fifth part a number of test papers have been given. The last two parts form a very important part of a student's preparation.

In a book of this nature, a balance has to be achieved between the number of questions and the quality of the questions, especially because it is relatively easy to frame a very large number of multiple-choice questions. The questions in this book have been selected keeping three things in mind. First, the questions are such that they really test the understanding of the subject. Second, among themselves, the questions cover all the concepts. Third, the number of questions has been kept large enough to offer meaningful practice to the students. Wherever required, hints have been given. In various competitive entrance examinations including the IIT-JEE, questions with multiple correct options are also asked sometimes. We have included questions of this type also. It should be remembered that in such questions marks are awarded only if all the correct options are chosen and no incorrect option is chosen.

We would like to thank the editors and production staff at Bharati Bhawan for their efforts in bringing out this revised edition of the book. Suggestions from readers for the improvement of the book are always welcome.

Authors

Contents

Part 1. Physical Chemistry

Part 2. Inorganic Chemistry

Part 3. Organic Chemistry

Part 4. Miscellaneous Questions

Part 5. Practice Test Papers

❑

Part 1

Physical Chemistry

1

Atomic Structure

• *Type 1* •

Choose the correct option. Only one option is correct.

1. A Cr atom in its ground state has a $3d^5\,4s^1$ configuration and a Cu atom a $3d^{10}\,4s^1$ configuration. This is because a shell which is half-filled or completely filled is particularly

(a) strongly exchange-destabilized

(b) weakly exchange-stabilized

(c) strongly exchange-stabilized

(d) weakly exchange-destabilized

2. A d-shell containing four unpaired electrons can exchange

(a) four electrons (b) three electrons

(c) sixteen electrons (d) six electrons

3. Based on quantum mechanical theory, the electronic configuration of Pd($Z = 46$) is

(a) $4d^9\,5s^1$ (b) $4d^{10}$

(c) $4d^8\,5s^1$ (d) $4d^{10}\,5s^2$

4. When a gold sheet is bombarded by a beam of α-particles, only a few of them get deflected whereas most go straight, undeflected. This is because

(a) the force of attraction exerted on the α-particles by the oppositely charged electrons is not sufficient

(b) a nucleus has a much smaller volume than that of an atom

(c) the force of repulsion acting on the fast-moving α-particles is very small

(d) the neutrons in the nucleus do not have any effect on the α-particles

5. Which of the following statements is incorrect for anode rays?

(a) They are deflected by electric and magnetic fields.

(b) Their *e/m* ratio depends on the gas in the discharge tube used to produce the anode rays.

(c) The *e/m* ratio of anode rays is constant.

(d) They are produced by the ionization of the gas in the discharge tube.

6. Rutherford's α-particle scattering experiment led to the conclusion that

(a) mass and energy are related

(b) the mass and the positive charge of an atom are concentrated in the nucleus

(c) neutrons are present in the nucleus

(d) atoms are electrically neutral

7. The radius of $^{27}_{13}Al$ will be

(a) 1.2×10^{-15} m (b) 27×10^{-15} m

(c) 10.8×10^{-15} m (d) 3.6×10^{-15} m

8. The density of the nucleus of an atom is

(a) 2.4×10^{15} kg m^{-3} (b) 2.4×10^{19} kg m^{-3}

(c) 2.4×10^{17} kg m^{-3} (d) 2.4×10^{14} kg m^{-3}

9. In an X-ray experiment, different metals are used as the target. In each case, the frequency ν of the radiation produced is measured. If Z = atomic number, which of the following plots will be a straight line?

(a) ν against Z (b) $\frac{1}{\nu}$ against Z

(c) $\sqrt{\nu}$ against Z (d) ν against $\sqrt{Z}$

10. In Moseley's equation $[\sqrt{\nu} = a(Z - b)]$, which was derived from the observations made during the bombardment of metal targets with X-rays,

(a) *a* is independent of but *b* depends on the metal

(b) both *a* and *b* depend on the metal

(c) both *a* and *b* are independent of the metal

(d) *b* is independent of but *a* depends on the metal

11. Which of the following reactions led to the discovery of the neutron?

(a) $^{14}_{6}C + ^{1}_{1}p \rightarrow ^{14}_{7}N + ^{1}_{0}n$ (b) $^{11}_{5}B + ^{2}_{1}D \rightarrow ^{12}_{6}C + ^{1}_{0}n$

(c) $^{9}_{4}Be + ^{4}_{2}He \rightarrow ^{12}_{6}C + ^{1}_{0}n$ (d) $^{8}_{4}Be + ^{4}_{2}He \rightarrow ^{11}_{6}C + ^{1}_{0}n$

12. Let m_p be the mass of a proton, m_n that of a neutron, M_1 that of a $^{20}_{10}Ne$ nucleus and M_2 that of a $^{40}_{20}Ca$ nucleus. Then

(a) $M_2 = 2M_1$ (b) $M_1 < 10(m_p + m_n)$

(c) $M_2 > 2M_1$ (d) $M_1 = M_2$

13. Positronium consists of an electron and a positron (a particle which has the same mass as an electron, but opposite charge) orbiting round their common centre of mass. Calculate the value of the Rydberg constant for this system.

(a) $R_\infty/2$ (b) $R_\infty/4$ (c) $2R_\infty$ (d) R_∞

14. What are the average distance and the most probable distance of an electron from the nucleus in the 1s orbital of a hydrogen atom (a_0 = the radius of the first Bohr orbit)?

(a) $1.5a_0$ and a_0 (b) a_0 and $5a_0$

(c) $1.5a_0$ and $0.5a_0$ (d) a_0 and $0.5a_0$

15. Calculate the mass of a deuteron, given that the first line in the Lyman series of hydrogen lies at 82259.1 cm^{-1}.

(a) 1.66×10^{-27} kg (b) 8.3×10^{-28} kg

(c) 6.68×10^{-27} kg (d) 3.34×10^{-27} kg

16. The energy of a 700-nm photon is

(a) 1.77 eV (b) 2.47 eV

(c) 700 eV (d) 3.57 eV

17. A 1-kW radio transmitter operates at a frequency of 880 Hz. How many photons per second does it emit?

(a) 1.71×10^{21} (b) 1.71×10^{30}

(c) 6.02×10^{23} (d) 2.85×10^{26}

18. The ratio of the *e/m* values of a proton and an α-particle is

(a) 2 : 1 (b) 1 : 1 (c) 1 : 2 (d) 1 : 4

19. Which of the following pairs have identical values of *e/m*?

(a) A proton and a neutron

(b) A proton and deuterium

(c) Deuterium and an α-particle

(d) An electron and γ-rays

20. Which of the following is an arrangement of increasing value of *e/m*?

(a) $n < \alpha < p < e$ (b) $e < p < \alpha < n$

(c) $n < p < e < \alpha$ (d) $p < n < \alpha < e$

21. Which particle among the following will have the smallest de Broglie wavelength, assuming that they have the same velocity?

(a) A positron (b) A photon

(c) An α-particle (d) A neutron

22. The velocity of the de Broglie wave is given by

(a) $\frac{c^2}{\nu}$ (b) $\frac{h\nu}{mc}$

(c) $\frac{mc^2}{h}$ (d) $\nu\lambda$

23. de Broglie wavelength is related to applied voltage as

(a) $\lambda = \frac{12.3}{\sqrt{h}}$ Å (b) $\lambda = \frac{12.3}{\sqrt{V}}$ Å

(c) $\lambda = \frac{12.3}{\sqrt{E}}$ Å (d) $\lambda = \frac{12.3}{\sqrt{m}}$ Å

24. Find the de Broglie wavelength of a 1-mg grain of sand blown by a 20-m s^{-1} wind.

(a) 3.3×10^{-29} m (b) 3.3×10^{-21} m

(c) 3.3×10^{-49} m (d) 3.3×10^{-42} m

25. The momentum of a hydrogen atom is given by

(a) $p = \frac{h\nu}{c}$ (b) $p = \frac{h\nu}{mc^2}$

(c) $p = \frac{mv}{h}$ (d) $p = mvr$

26. For an electron, the product vn (velocity $\times$ principal quantum number) will be independent of the

(a) principal quantum number

(b) velocity of the electron

(c) energy of the electron

(d) frequency of its revolution

27. Assume that the potential energy of a hydrogen atom in its ground state is zero. Then its energy in the first excited state will be

(a) 13.6 eV (b) 27.2 eV

(c) 23.8 eV (d) 10.2 eV

28. The ratio of $E_2 - E_1$ to $E_4 - E_3$ for the hydrogen atom is approximately equal to

(a) 10 (b) 15 (c) 17 (d) 12

29. The ionization energy of a hydrogen atom is 13.6 eV. The energy of the third-lowest electronic level in doubly ionized lithium ($Z = 3$) is

(a) −28.7 eV (b) −54.4 eV

(c) −122.4 eV (d) −13.6 eV

30. What is the most probable distance from the nucleus at which a 2p electron will be found in the hydrogen atom?

(a) 53 pm (b) 106 pm

(c) 212 pm (d) 26.5 pm

31. The energy needed to excite a hydrogen atom from its ground state to its third excited state is

(a) 12.1 eV (b) 10.2 eV

(c) 0.85 eV (d) 12.75 eV

32. The frequency of one of the lines in the Paschen series of a hydrogen atom is 2.34×10^{14} Hz. The quantum number n_2 which causes this transition is

(a) 3 (b) 4 (c) 6 (d) 5

33. The line spectra of two elements are not identical because

(a) the elements do not have the same number of neutrons

(b) they have different mass numbers

(c) their outermost electrons are at different energy levels

(d) they have different valencies

34. The wavelength of the third line of the Balmer series for a hydrogen atom is

(a) $\dfrac{21}{100R_\infty}$ (b) $\dfrac{100}{21R_\infty}$

(c) $\dfrac{21R_\infty}{100}$ (d) $\dfrac{100R_\infty}{21}$

35. In which of the following transitions will the wavelength be minimum?

(a) $n = 6$ to $n = 4$ (b) $n = 4$ to $n = 2$

(c) $n = 3$ to $n = 1$ (d) $n = 2$ to $n = 1$

36. In which of the following is the radius of the first orbit minimum?

(a) A hydrogen atom (b) A tritium atom

(c) Triply ionized beryllium (d) Doubly ionized helium

37. When the electron of a hydrogen atom jumps from the $n = 4$ to the $n = 1$ state, the number of spectral lines emitted is

(a) 15 (b) 6

(c) 3 (d) 4

38. The quantum number not obtained from the Schrödinger wave equation is

(a) n (b) l

(c) m_l (d) m_s

39. If a magnetic field is applied to the electron of a hydrogen atom in the z-direction, the z-component of the spin angular momentum is given by

(a) $s_z = \sqrt{s(s+1)}$ (b) $s_z = \frac{\sqrt{3}}{2} \times \frac{h}{2\pi}$

(c) $s_z = m_s \frac{h}{4\pi}$ (d) $s_z = \pm\frac{1}{2} \times \frac{h}{2\pi}$

40. What are the values of the orbital angular momentum of an electron in the orbitals 1s, 3s, 3d and 2p?

(a) $0, 0, \sqrt{6}\hbar, \sqrt{2}\hbar$ (b) $1, 1, \sqrt{4}\hbar, \sqrt{2}\hbar$

(c) $0, 1, \sqrt{6}\hbar, \sqrt{3}\hbar$ (d) $0, 0, \sqrt{20}\hbar, \sqrt{6}\hbar$

41. In an excited state, a calcium atom has the electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s4d$. What is the angular momentum of this state?

(a) $\sqrt{4}\hbar$ (b) $\sqrt{16}\hbar$

(c) $\sqrt{20}\hbar$ (d) $\sqrt{10}\hbar$

42. For a hydrogen atom, what is the orbital degeneracy of the level that has energy $= \frac{-hcR_\infty}{9}$, where R_∞ is the Rydberg constant for the hydrogen atom?

(a) 1 (b) 9

(c) 36 (d) 3

43. The maximum number of electrons in a subshell is given by the expression

(a) $4l - 2$ (b) $4l + 2$ (c) $2l + 1$ (d) $2n^2$

44. The total number of subshells in the nth energy level is

(a) n^2 (b) $2n^2$ (c) $n - 1$ (d) n

45. When the value of the azimuthal quantum number is 3, the maximum and the minimum values of the spin multiplicities are

(a) 4, 3 (b) 8, 1 (c) 1, 3 (d) 8, 2

46. If the value of the principal quantum number is 3, the maximum number of values the magnetic quantum number can have is

(a) one (b) four

(c) nine (d) twelve

47. The correct set of quantum numbers for the unpaired electron of a chlorine atom is

(a) $2, 0, 0, +\frac{1}{2}$ (b) $2, 1, -1, +\frac{1}{2}$

(c) $3, 1, -1, \pm\frac{1}{2}$ (d) $3, 0, 0, \pm\frac{1}{2}$

48. The Pauli exclusion principle is not applicable to

(a) electrons (b) positrons (c) photons (d) protons

49. Four sets of values of quantum numbers (n, l, m and s) are given below. Which of these does not provide a permissible solution of the wave equation?

(a) $3, 2, -2, \frac{1}{2}$ (b) $3, 3, 1, -\frac{1}{2}$

(c) $3, 2, 1, \frac{1}{2}$ (d) $3, 1, 1, -\frac{1}{2}$

50. Which of the following sets of quantum numbers represents the highest energy of an atom?

(a) $n = 4, l = 0, m = 0, s = +\frac{1}{2}$ (b) $n = 3, l = 0, m = 0, s = +\frac{1}{2}$

(c) $n = 3, l = 1, m = 1, s = +\frac{1}{2}$ (d) $n = 3, l = 2, m = 1, s = +\frac{1}{2}$

51. The four quantum numbers of the valence electron of potassium are

(a) $4, 1, 1, \frac{1}{2}$ (b) $4, 0, 0, \frac{1}{2}$ (c) $4, 1, 0, \frac{1}{2}$ (d) $4, 4, 0, \frac{1}{2}$

52. The following sets of quantum numbers represent four electrons in an atom.

(i) $n = 4, l = 1$ (ii) $n = 4, l = 0$ (iii) $n = 3, l = 2$ (iv) $n = 3, l = 1$

In this context, which of the following represents the order of increasing energy?

(a) (iv) < (ii) < (iii) < (i) (b) (ii) < (iv) < (i) < (iii)

(c) (i) < (iii) < (ii) < (iv) (d) (iii) < (i) < (iv) < (ii)

53. The total number of orbitals in a shell with principal quantum number n is

(a) $2n$ (b) $2n^2$ (c) n^2 (d) $n + 1$

54. If m = magnetic quantum number and l = azimuthal quantum number, then

(a) $m = l + 2$ (b) $m = 2l^2 + 1$

(c) $l = \frac{m - 1}{2}$ (d) $l = 2m + 1$

55. Which of the following sets of quantum numbers represents the 19th electron of chromium ($Z = 24$)?

(a) $4, 0, 0, +\frac{1}{2}$ (b) $4, 1, -1, +\frac{1}{2}$

(c) $3, 2, 2, +\frac{1}{2}$ (d) $3, 2, -2, +\frac{1}{2}$

56. Which option gives the values of the quantum numbers for the 21st electron of scandium ($Z = 21$)?

(a) $3, 1, 1, +\frac{1}{2}$ (b) $3, 2, 2, +\frac{1}{2}$

(c) $3, 2, -2, -\frac{1}{2}$ (d) $3, 2, 2, -\frac{1}{2}$

57. The electronic configuration of Fe^{3+} is

(a) $[Ar]3d^5 4s^1$ (b) $[Ar]3d^6 4s^0$

(c) $[Ar]3d^5 4s^0$ (d) $[Ar]3d^6 4s^2$

58. The number of unpaired electrons in Mn^{4+} ($Z = 25$) is

(a) four (b) two

(c) five (d) three

59. The configuration $[Ar]3d^{10}4s^2 4p^1$ is similar to that of

(a) carbon (b) oxygen

(c) nitrogen (d) aluminium

60. Among the following, the configuration $1s^2 2s^2 2p^5 3s^1$ is valid for the

(a) ground state of fluorine (b) excited state of fluorine

(c) excited state of neon (d) excited state of the O_2^- ion

61. After np orbitals are filled, the next orbital filled will be

(a) $(n + 1)$s (b) $(n + 2)$p

(c) $(n + 1)$d (d) $(n + 2)$s

62. The value of the magnetic moment of a particular ion is 2.83 Bohr magneton. The ion is

(a) Fe^{2+} (b) Ni^{2+}

(c) Mn^{2+} (d) Co^{3+}

63. Which of the following violates the Pauli exclusion principle?

(a) $\boxed{\uparrow\downarrow}\quad\boxed{\uparrow\downarrow}\boxed{}\boxed{}$ (b) $\boxed{\uparrow\downarrow}\quad\boxed{\uparrow}\boxed{\downarrow}\boxed{\uparrow}$

(c) $\boxed{\uparrow\uparrow}\quad\boxed{\uparrow}\boxed{\uparrow}\boxed{\uparrow}$ (d) $\boxed{\uparrow}\quad\boxed{\uparrow}\boxed{\uparrow}\boxed{\uparrow}$

64. Which of the following violates the Aufbau principle?

	2s	2p		
(a)	↑↓	↑↓	↑	
(b)	↑↓	↑↓	↑↓	↑
(c)	↑↑	↑↓	↑↓	↑
(d)	↑	↑↓	↑	↑

65. Which of the following electronic configurations have the highest exchange energy?

	3d					4s
(a)	↑	↑	↑			↑
(b)	↑	↑	↑	↑	↑	↑
(c)	↑↓	↑↓	↑↓	↑↓	↑	↑
(d)	↑↓	↑↓	↑↓	↑↓	↑↓	↑

66. Which of the following sets of orbitals is arranged in the correct order of increasing energy?

(a) 3d < 4s < 4p < 6s < 4d (b) 2s < 3d < 4p < 4f < 1s

(c) 4s < 3d < 4p < 5s < 4d (d) 1s < 2s < 2p < 4d < 3f

67. The number of spherical nodes in 3p orbitals is

(a) one (b) three

(c) two (d) zero

68. In which of the following orbitals is there zero probability of finding the electron in the *xy* plane?

(a) p_x (b) d_{yz} (c) $d_{x^2-y^2}$ (d) p_z

69. Which of the following electronic configurations have zero spin multiplicity?

(a)	↑	↑	↑
(b)	↑	↑	↓
(c)	↑	↓	↓
(d)	↓	↓	↓

70. The radial distribution functions for all orbitals is given by

(a) $n + l$ (b) $n - l - 1$

(c) $n - l - 2$ (d) $n - l + 1$

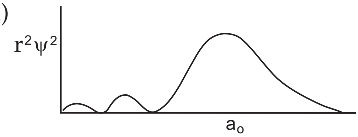
71. The angular distribution functions of all orbitals have

(a) l nodal surfaces (b) $l-1$ nodal surfaces

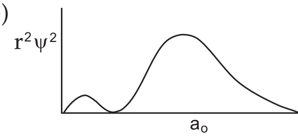
(c) $n+l$ nodal surfaces (d) $n-l-1$ nodal surfaces

72. Which of the following radial distribution graphs correspond to $l = 2$ for the H atom?

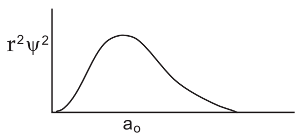
(a)



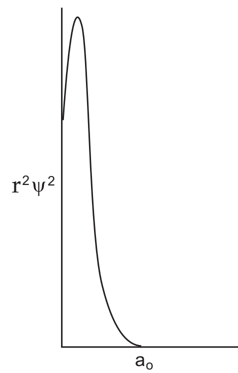
(b)



(c)

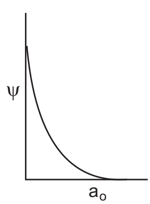


(d)

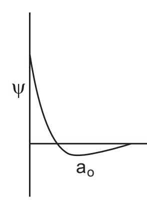


73. Which of the following graphs correspond to one node?

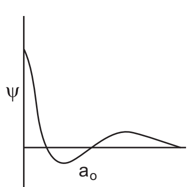
(a)



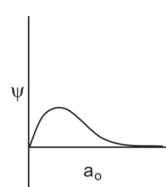
(b)



(c)



(d)



74. Which of the following statements is incorrect with reference to the Zeeman effect?

(a) In a magnetic field, the energy of a particular atomic state depends on the values of m_l and n.

(b) Individual spectral lines are split into separate lines. The distance between them is independent of the magnitude of the field.

(c) The Zeeman effect involves the splitting of a spectral line of frequency ν_0 into three components whose frequencies are

$$\nu_1 = \nu_0 - \frac{e}{4\pi m}B, \nu_2 = \nu_0 \text{ and } \nu_3 = \nu_0 + \frac{e}{4\pi m}B,$$

where B is the magnetic field applied on the spectral line.

(d) From the Zeeman effect, one can calculate the e/m ratio for an electron.

75. The wave function for a hydrogen atom with its electron in the 2p state varies with direction as well as distance from the nucleus. What is the probability of a 2p electron, for which $m_l = 0$, existing on the xy plane?

(a) 0 (b) 1 (c) $2a_0$ (d) a_0

• Type 2 •

Choose the correct options. More than one option is correct.

76. Which of the following is true for Thomson's model of the atom?

(a) The radius of an electron can be calculated using this model.

(b) In an undisturbed atom, the electrons will be at their equilibrium positions, where the attraction between the cloud of positive charge and the electrons balances their mutual repulsion.

(c) When the electrons are disturbed by collision, they will vibrate around their equilibrium positions and emit electromagnetic radiation. The frequency of this radiation is of the order of magnitude of the frequency of electromagnetic radiation, typical of these electrons.

(d) It can explain the existence of protons.

77. From the α-particle scattering experiment, Rutherford concluded that

(a) α-particles can come within a distance of the order of 10^{-14} m of the nucleus

(b) the radius of the nucleus is less than 10^{-14} m

(c) scattering follows Coulomb's law

(d) the positively charged parts of the atom move with extremely high velocities

78. Rutherford's scattering formula fails for very small scattering angles because

(a) the full nuclear charge of the target atom is partially screened by its electron

(b) the impact parameter between the α-particle source and the nucleus of the target is very large compared to the size of the nucleus
(c) the kinetic energy of the α-particles is large
(d) the gold foil is very thin

79. Which of the following transitions are allowed in the normal electronic emission spectrum of an atom?

(a) $2s \rightarrow 1s$ (b) $2p \rightarrow 1s$ (c) $3d \rightarrow 2p$ (d) $5p \rightarrow 3s$

80. Choose the correct statements.

(a) Every object emits radiation whose predominant frequency depends on its temperature.
(b) The quantum energy of a wave is proportional to its frequency.
(c) Photons are quanta of light.
(d) The value of the Planck constant depends on energy.

81. The mathematical expression for the uncertainty principle is

(a) $\Delta x \, \Delta p \geq \frac{h}{4\pi}$ (b) $\Delta E \, \Delta t \geq \frac{h}{4\pi}$

(c) $\Delta x \, \Delta p \geq \frac{h}{p}$ (d) $\Delta E \, \Delta t \geq \frac{h}{p}$

82. To which of the following is Bohr's theory applicable?

(a) He^{+} (b) Li^{2+}

(c) Tritium (d) Be^{3+}

83. Bohr's theory is not applicable to

(a) He (b) Li^{2+}

(c) He^{2+} (d) the H atom

84. Choose the correct relations on the basis of Bohr's theory.

(a) Velocity of electron $\propto \frac{1}{n}$

(b) Frequency of revolution $\propto \frac{1}{n^3}$

(c) Radius of orbit $\propto n^2 Z$

(d) Force on electron $\propto \frac{1}{n^4}$

85. The change in orbital angular momentum corresponding to an electron transition inside a hydrogen atom can be

(a) $\frac{h}{4\pi}$ (b) $\frac{h}{\pi}$ (c) $\frac{h}{2\pi}$ (d) $\frac{h}{8\pi}$

86. The magnitude of the spin angular momentum of an electron is given by

(a) $S = \sqrt{s(s+1)}\,\dfrac{h}{2\pi}$ (b) $S = s\,\dfrac{h}{2\pi}$

(c) $S = \dfrac{\sqrt{3}}{2} \times \dfrac{h}{2\pi}$ (d) $S = \pm\dfrac{1}{2} \times \dfrac{h}{2\pi}$

87. Choose the correct configurations from among the following.

(a) Cr(Z = 24) : [Ar]$3d^5\,4s^1$ (b) Cu(Z = 29) : [Ar]$3d^{10}\,4s^1$

(c) Pd(Z = 46) : [Kr]$4d^{10}\,4s^0$ (d) Pt(Z = 78) : [Xe]$4d^{10}\,4s^2$

88. The configuration [Ar]$3d^{10}4s^24p^2$ is similar to that of

(a) boron (b) oxygen

(c) sulphur (d) aluminium

89. In which of these options do both constituents of the pair have the same magnetic moment?

(a) Zn^{2+} and Cu^{+} (b) Co^{2+} and Ni^{2+}

(c) Mn^{4+} and Co^{2+} (d) Mg^{2+} and Sc^{+}

90. Which of the following ions are diamagnetic?

(a) He_2^+ (b) Sc^{3+} (c) Mg^{2+} (d) O_2^{2-}

91. The ground-state electronic configuration of the nitrogen atom can be represented as

(a) $\boxed{\uparrow\downarrow}$ $\boxed{\uparrow\downarrow}$ $\boxed{\uparrow\,|\,\uparrow\,|\,\uparrow}$ (b) $\boxed{\uparrow\downarrow}$ $\boxed{\uparrow\downarrow}$ $\boxed{\uparrow\,|\,\downarrow\,|\,\uparrow}$

(c) $\boxed{\uparrow\downarrow}$ $\boxed{\uparrow\downarrow}$ $\boxed{\uparrow\,|\,\downarrow\,|\,\downarrow}$ (d) $\boxed{\uparrow\downarrow}$ $\boxed{\uparrow\downarrow}$ $\boxed{\downarrow\,|\,\downarrow\,|\,\downarrow}$

92. Choose the correct statements from among the following.

(a) A node is a point in space where the wave function (Ψ) has zero amplitude.

(b) The number of peaks in radial distribution is $n - l$.

(c) Radial probability density $\rho_{n,l}(r) = 4\pi r^2 R_{n,l}^2(r)$.

(d) Ψ^2 represents the atomic orbital.

Answers

1. c	**2.** d	**3.** b	**4.** b	**5.** c
6. b	**7.** d	**8.** c	**9.** c	**10.** d
11. c	**12.** b	**13.** a	**14.** a	**15.** d
16. a	**17.** b	**18.** a	**19.** c	**20.** a

21. c	**22.** b	**23.** b	**24.** a	**25.** a
26. a	**27.** c	**28.** b	**29.** c	**30.** b
31. d	**32.** d	**33.** c	**34.** b	**35.** c
36. c	**37.** b	**38.** d	**39.** d	**40.** a
41. c	**42.** b	**43.** b	**44.** d	**45.** d
46. c	**47.** c	**48.** c	**49.** b	**50.** d
51. b	**52.** a	**53.** c	**54.** c	**55.** a
56. b	**57.** c	**58.** d	**59.** d	**60.** c
61. a	**62.** b	**63.** c	**64.** d	**65.** d
66. c	**67.** a	**68.** d	**69.** c	**70.** b
71. a	**72.** c	**73.** b	**74.** b	**75.** a
76. b, c	**77.** a, b, c	**78.** a, b	**79.** b, c, d	**80.** a, b, c
81. a, b	**82.** a, b, c, d	**83.** a, c	**84.** a, b, d	**85.** b, c
86. a, c	**87.** a, b, c	**88.** b, c	**89.** a, c	**90.** b, c, d
91. a, d	**92.** a, b, c, d			

Hints to More Difficult Problems

2. $n_{C_2} = 4_{C_2} = \dfrac{4\,!}{2\,!\,2\,!} = 6.$

7. $r = 1.2 \times 10^{-15} A^{1/3}\text{m}.$

For Al, $A = 270$.

$\therefore \quad r = 1.2 \times 10^{-15}(27)^{1/3}\text{m} = 3.6 \times 10^{-15}$ m.

8. $$\rho = \frac{Au}{\frac{4}{3}\pi\,[1.2 \times 10^{-15} A^{1/3}]^3} = \frac{u}{(1.33\pi(1.2 \times 10^{-15})^3}$$

$$= \frac{1.66 \times 10^{-27}\,\text{kg}}{1.33\pi(1.2 \times 10^{-15})^3\text{m}^3} = 2.4 \times 10^{17}\,\text{kg m}^{-3}.$$

9. Using Moseley's equation $\nu = a(Z - b)^2$, $\sqrt{\nu} = \sqrt{a}(Z - b) = \sqrt{a}\,Z - \sqrt{ab}$ which is in the form of $y = mx + c$. Therefore, a plot of $\sqrt{\nu}$ against Z is a straight line.

13. The reduced mass is given by

$$\mu = \frac{m_e m_e^+}{m_e + m_e^+} = \frac{m_e^2}{2m_e} \text{ (mass of electron = mass of positron)}$$

$$\mu = \frac{1}{2} m_e$$

$\therefore$ Rydberg constant $= R_\infty/2$

16. $E = \dfrac{hc}{\lambda} = \dfrac{1242 \text{ eV.nm}}{\lambda} = \dfrac{1242 \text{ eV.nm}}{700 \text{ nm}} = 1.77 \text{ eV.}$

17. $E = h\nu = (6.626 \times 10^{-34} \text{ Js})\,(880 \text{ s}^{-1})$

$= 5.831 \times 10^{-31}$ J.

No. of photons emitted $= \dfrac{1}{5.831} \times 10^{+31} = 1.71 \times 10^{30}$ per second.

18. For a proton $({}^1_1\text{H})$, $\dfrac{e}{m} = \dfrac{1}{1}\cdot$

For an α-particle $({}^4_2\text{He})$, $\dfrac{e}{m} = \dfrac{2}{4} = \dfrac{1}{2}\cdot$

$\dfrac{(e/m)_p}{(e/m)_\alpha} = \dfrac{1/1}{1/2} = 2:1.$

21. The de Broglie equation is $\lambda = \dfrac{h}{p} = \dfrac{h}{mv}\cdot$

Here h and v are constant. So $\lambda \propto \dfrac{1}{m}\cdot$

Since the α-particle has the highest mass among the given entities, it has the smallest de Broglie wavelengths.

22. Momentum $= p = \dfrac{h\nu}{c}\cdot$

$\therefore \quad mv = \dfrac{h\nu}{c} \Rightarrow v = \dfrac{h\nu}{mc}\cdot$

23. $E = eV = \dfrac{1}{2}mv^2 = \dfrac{p^2}{2m},$

where V = applied voltage.

We know that $\lambda = \dfrac{h}{p}\cdot$

$2meV = p^2 \Rightarrow p = \sqrt{2meV}.$

$\therefore \quad \lambda = \dfrac{h}{\sqrt{2meV}} = \dfrac{12.3}{\sqrt{V}}$ Å.

26. We know that $v \propto \dfrac{1}{n}$ and n = principal quantum number. Therefore, vn will be independent of the principal quantum number.

27. $-\text{PE} = 2\text{KE} = 2 \times (+13.6) = 27.2$ eV.

$\therefore \quad \text{PE} = -27.2$ eV

PE with respect to ground state = 27.2 eV which we assume to be zero.

$$\text{KE} = -\frac{13.6}{n^2} \text{ eV.}$$

For the first excited state, $n = 2$.

$\therefore$ $KE = -\dfrac{13.6}{2^2}\,eV = -3.4\ eV$

Total energy = $(27.2 - 3.4)\ eV = 23.8\,eV$.

31. $E_n = -\dfrac{13.6}{n^2}Z^2$, where $n = 1$ for ground state, 2 for first excited state, and so on. $Z = 1$ for hydrogen.

34. $\dfrac{1}{\lambda} = R_\infty\left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right)$ for the H atom.

For the Balmer series,

$n_1 = 2$ and $n_2 = 5$ (for the third line).

$\dfrac{1}{\lambda} = R_\infty\left(\dfrac{1}{2^2} - \dfrac{1}{5^2}\right) = \dfrac{21}{100}R_\infty.$

$\therefore$ $\lambda = \dfrac{100}{21}R_\infty.$

37. N = number of lines emitted $= \dfrac{1}{2}n(n-1)$

$= \dfrac{1}{2} \times 4(4-1) = 6.$

42. Here $n = 3$, which corresponds to 3s, 3p, 3d orbitals which have a degeneracy $= 1 + 3 + 5 = 9$.

45. $l = 3$ corresponds to s, p, d and f orbitals.

Maximum multiplicity for the f orbitals (7 electrons)

$$= 2s + 1 = 2 \times \frac{7}{2} + 1 = 8.$$

Minimum multiplicity for the f orbital (1 electron)

$$= 2s + 1 = 2 \times \frac{1}{2} + 1 = 2.$$

49. $n = l$ is not permissible.

50. The state corresponds to the 3d atomic orbitals.

55. The 19th electron corresponds to the 4s orbital. For this orbital,

$$n = 4,\ l = 0,\ m = 0,\ s = \frac{1}{2}\cdot$$

56. The 21st electron corresponds to $3d^1$. For this orbital,

$$n = 3,\ l = 2,\ m = 2,\ s = +\frac{1}{2}\cdot$$

57. $Fe(Z = 26) = [Ar]\ 3d^6 4s^2$

Fe^{3+}(23 electrons) = $[Ar]\ 3d^5$

58. Mn^{4+} (21 electrons) = $[Ar]\ 3d^3$ contains three unpaired electrons.

61. Follow the Aufbau principle.

62. The spin-only formula is given by

$\mu_{\text{spin only}} = \sqrt{s(s+1)}$ BM

The value of $\mu = 2.83$ BM corresponds to the presence of two unpaired electrons. So the ion is $Ni^{2+}(3d^8)$.

66. Use the energy-level diagram.

67. For the 3p orbital, $n = 3$, $l = 1$.

The number of spherical nodes

$= n - l - 1 = 3 - 1 - 1 = 1.$

69. Spin multiplicity = $(2\Sigma s + 1)$.

82. All the species have one electron each. So Bohr's theory is applicable.

83. Because He and He^{2+} have two electrons and no electron respectively, Bohr's theory is not applicable to them.

88. Boron ($1s^2 2s^2 2p^1$) as well as aluminium ($1s^2 2s^2 2p^6 3s^2 3p^1$) have an s^2p^1 configurations, and so does [Ar] ($3d^{10}\, 4s^2\, 4p^1$).

89. Zn^{2+} and Cu^+ have a $3d^{10}$ configuration, $n = 0$.

Mn^{4+} and Co^+ have a $3d^3$ configuration, $n = 3$.

90. The number of unpaired electrons is zero. So $\mu = 0$ BM.

❑

2

Nuclear Chemistry

• *Type 1* •

Choose the correct option. Only one option is correct.

1. In radioactive decay, the emitted electrons come from the
- (a) innermost shell of the atom
- (b) K shell of an atom
- (c) outermost shell of the atom
- (d) decay of neutrons in the nucleus

2. In the radioactive decay ${}^{232}_{92}X \longrightarrow {}^{220}_{89}Y$, how many α- and β-particles are ejected from X and Y?

(a) 5 α and 5 β (b) 3 α and 3 β
(c) 3 α and 5 β (d) 5 α and 6 β

3. In the radioactive decay

$$ {}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y \longrightarrow {}^{A-4}_{Z-1}Z \longrightarrow {}^{A-4}_{Z-1}Z^{*} $$

the sequence of the radiation emitted is

(a) α, β, γ (b) β, α, γ (c) γ, α, β (d) β, γ, α

4. In nature, which of the following nuclear reactions lead to the formation of tritium?

(a) ${}^{6}_{3}Li + {}^{1}_{0}n \rightarrow {}^{4}_{2}He + {}^{3}_{1}H$ (b) ${}^{10}_{5}B + {}^{1}_{1}p \rightarrow {}^{8}_{5}B + {}^{3}_{1}H$
(c) ${}^{11}_{5}B + {}^{2}_{1}D \rightarrow {}^{10}_{5}B + {}^{3}_{1}H$ (d) ${}^{9}_{4}Be + \gamma \rightarrow {}^{6}_{2}He + {}^{3}_{1}H$

5. Which of the following nuclear reactions in nature lead to the formation of radiocarbon?

(a) ${}^{16}_{8}O + {}^{14}_{7}N \rightarrow {}^{14}_{6}C + {}^{16}_{9}F$ (b) ${}^{14}_{7}N + {}^{1}_{0}n \rightarrow {}^{14}_{6}C + {}^{1}_{1}H$
(c) ${}^{14}_{7}N + {}^{1}_{0}n \rightarrow {}^{14}_{6}C + {}^{2}_{1}H$ (d) ${}^{14}_{7}N + {}^{3}_{1}H \rightarrow {}^{14}_{6}C + {}^{3}_{2}He$

6. Which of the following nuclei are β^+-emitters?

(a) Antinutrino (b) Potassium-40

(c) Radon-222 (d) Chlorine-34

7. Which of the following radioactive elements are soluble in water?

(a) Radium (b) Radon

(c) Technetium (d) Tritium

8. During the transformation of ${}^{a}_{c}X$ to ${}^{b}_{d}Y$, the number of β-particles emitted is

(a) $\frac{a-b}{4}$ (b) $d+\frac{a-b}{2}+c$

(c) $d+\left[\frac{a-b}{2}\right]-c$ (d) $2c-d+a-b$

9. The nucleus of an electrically neutral atom undergoes radioactive decay. It will remain neutral after the decay if the process is a

(a) β^--decay (b) β^+-decay

(c) γ-decay (d) neutron decay

10. Consider the following decay.

$$ {}^{A}_{Z}X \rightarrow {}^{\;\;A}_{Z+1}Y + {}^{\;\;0}_{-1}e + \bar{\nu} $$

X is unstable because

(a) of its large nuclide

(b) its nucleus has excess energy

(c) the nuclide has more neutrons than protons

(d) the nuclide has more protons than neutrons

11. A radioactive nuclide emits γ-rays due to the

(a) emission of an electron from its orbital

(b) nuclear transition from a higher state to a lower state

(c) presence of more neutrons than protons

(d) presence of less neutrons than protons

12. Which of the following combinations will give the most stable nuclei?

(a) Odd Z and odd N (b) Even Z and even N

(c) Odd Z and even N (d) Even Z and odd N

13. ${}^{27}_{13}Al$ is a stable isotope. It is expected to disintegrate by

(a) α-emission (b) β^--emission

(c) β^+-emission (d) proton emission

14. In radioactive decay, which of the following move the fastest?

(a) α-particles (b) β^--particles

(c) γ-rays (d) Positrons

15. Which of the following combinations would make the nucleus unstable?

(a) $N > 126, Z > 83, A < 208$ (b) $N > 126, Z > 83, A > 209$

(c) $Z > 82, N < 126, A > 108$ (d) $Z = 83, N = 126, A > 209$

16. For stable nuclei, the average binding energy per nucleon lies between

(a) 7 and 9 MeV (b) 10 and 12 MeV

(c) 2 and 4 MeV (d) 5 and 7 MeV

17. The most stable nuclei found in the binding-energy curve are those of

(a) Cu (b) Fe

(c) C (d) Pb

18. Which of the following radioactive series is artificial?

(a) Thorium series ($4n$) (b) Neptunium series ($4n+1$)

(c) Uranium series ($4n+2$) (d) Actinium series ($4n+3$)

19. ${}^{219}_{84}$Rn is a member of the actinium series. Another member of the same series is

(a) ${}^{235}_{91}$Pa (b) ${}^{232}_{90}$Th

(c) ${}^{235}_{92}$U (d) ${}^{227}_{88}$Ra

20. Among the following, which has the longest half-life?

(a) ${}^{232}_{90}$Th (b) ${}^{237}_{93}$Np

(c) ${}^{238}_{92}$U (d) ${}^{235}_{92}$U

21. The analysis of a rock shows that the relative number of ^{206}Pb and ^{238}U atoms is Pb/U = 0.25. If $t_{1/2}$ for the reaction ${}^{238}\text{U} \rightarrow {}^{206}\text{U}$ is 4×10^9 years, the age of the rock (in years) is

(a) $\dfrac{2.303}{0.693}(4 \times 10^9) \log \dfrac{5}{4}$ (b) $\dfrac{2.303}{0.693}(4 \times 10^9) \log \dfrac{1}{4}$

(c) $\dfrac{2.303}{0.693}(4 \times 10^9) \log 4$ (d) $\dfrac{2.303}{0.693}(4 \times 10^9) \log \dfrac{4}{5}$

22. A certain radioactive isotope ${}^{A}_{Z}\text{X}$($t_{1/2}$ = 10 days) decays to ${}^{A-4}_{Z-2}\text{Y}$. If 1 mol of ${}^{A}_{Z}\text{X}$ is kept in a sealed vessel, how much ion will accumulate in 20 days?

(a) 22.4 L (b) 11.2 L

(c) 16.8 L (d) 33.6 L

23. A radioelement decays by two parallel reactions, the decay constants for which are λ_1 and λ_2. The effective decay constant (λ) of the nuclide is

(a) $\lambda = \lambda_1 / \lambda_2$ (b) $\lambda = \lambda_1 - \lambda_2$

(c) $\lambda = \lambda_1 + \lambda_2$ (d) $\lambda = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$

24. The time of decay for a nuclear reaction is given by $t = 4t_{1/2}$. The relation between the mean life (T) and time of decay (t) is given by

(a) $2T \ln 2$ (b) $4T \ln 2$

(c) $2T^4 \ln 2$ (d) $\frac{1}{T^2} \ln 2$

25. A freshly prepared radioelement has a half-life of 2 hours. It emits radiation whose intensity is 64 times the permissible safe level. The minimum time after which it would be possible to work with this sample is

(a) 3 hours (b) 9 hours

(c) 24 hours (d) 12 hours

26. The activity of a sample of a radioactive nuclide (^{100}X) is 6.02 curies. Its disintegration constant is $3.7 \times 10^4 \, s^{-1}$. The initial mass of the sample is

(a) 1×10^{-14} g (b) 1×10^{-6} g

(c) 1×10^{-15} g (d) 1×10^{-3} g

27. The half-life of a radioactive sample is $2n$ years. What fraction of this sample will remain undecayed after n years?

(a) $\frac{1}{2}$ (b) $\frac{1}{\sqrt{2}}$

(c) $\frac{1}{\sqrt{3}}$ (d) 2

28. One gram of ^{226}Ra has an activity of nearly 1 Ci. The $t_{1/2}$ of ^{226}Ra is

(a) 1620 years (b) 12.5 years

(c) 140 days (d) 4.5×10^9 years

29. A sample of a radioisotope ($t_{1/2}$ = 3 days) was taken. After 12 days, 3 g of the sample was left. What was the initial mass of the sample?

(a) 112 g (b) 136 g (c) 12 g (d) 48 g

30. The rate of decay of a radioactive sample is given by R_1 at time t_1, and R_2 at a later time t_2. The mean life of this radioactive sample is

(a) $T = \frac{R_1}{R_2} \times \frac{t_2}{t_1}$ (b) $T = (t_1 - t_2)/ \ln (R_2/R_1)$

(c) $T = (t_2 - t_1)/ \ln (R_2/R_1)$ (d) $T = \frac{\ln (R_2/R_1)}{t_1 - t_2}$

31. The count rate of 200 mL of a radioactive liquid sample is x. Some of the liquid is now discarded. The count rate of the remaining liquid is found to be $x/20$ after four half-lives. The volume in millilitres of the remaining liquid is

(a) 160 (b) 80 (c) 40 (d) 10

32. Which of the following is a β^+ emitter?

(a) $^{49}_{20}Ca$ (b) $^{8}_{5}B$ (c) $^{208}_{82}Pb$ (d) $^{94}_{36}Kr$

33. The half-life of a 4.00-mg sample of ^{210}RaE is 5 days and the average energy of the β-particle emitted is 0.34 MeV. At what rate in watts does the sample emit energy?

(a) 2.0 (b) 0.1

(c) 1.5 (d) 1.0

34. 80% of the radioactive nuclei present in a sample are found to remain undecayed after one day. The percentage of undecayed nuclei left after two days will be

(a) 64 (b) 20

(c) 46 (d) 80

35. Assuming that ^{226}Ra ($t_{1/2} = 1.6 \times 10^3$ yr) is in secular equilibrium with ^{238}U ($t_{1/2} = 4.5 \times 10^9$ yr) in a certain mineral, how many grams of Ra will be present for every gram of ^{238}U in this mineral?

(a) 3.7×10^{-7} (b) 3.4×10^{7}

(c) 3.4×10^{-7} (d) 3.7×10^{7}

36. Which of the following processes results in an increase in the atomic number of a nuclide?

(a) Alpha emission (b) Electron capture

(c) Beta emission (d) Positron emission

37. Which of the following processes causes the emission of an X-ray?

(a) Alpha emission (b) Gamma emission

(c) Positron emission (d) Electron capture

38. With increasing nuclear size,

(a) the repulsive force between the protons increases and so does the energy of the nucleus

(b) the repulsive force between the protons decreases and the energy of the nucleus increases

(c) the attractive force between the protons increases and so does the energy of the nucleus

(d) the attractive force between the protons decreases and so does the energy of the nucleus

39. Temperature has no effect on rate of decay because
(a) nuclear energies are very high
(b) nuclear energies are low
(c) radioactive decay is a statistical process
(d) radioactive decay follows exponential law

40. Nuclear isomers are nuclei with the same
(a) number of electrons, protons and electrons, and have the same half-life
(b) number of protons and neutrons but their energy levels are different
(c) number of protons and neutrons, and the same energy levels
(d) value of half-life and average life

41. Sometimes the ejection of an α-particle does not completely stabilize the nucleus. In such a case more α-particles may be emitted. α-decay
(a) raises the N/P ratio and is often followed by β-emission
(b) lowers the N/P ratio and is often followed by positron emission
(c) raises the N/P ratio and is often followed by neutron emission
(d) lowers the N/P ratio and is often followed by γ-ray emission

42. The age of a specimen, t, is related to the daughter/parent ratio D/P by the equation
(a) $t = \frac{1}{\lambda} \ln \frac{D}{P}$ (b) $t = \frac{1}{\lambda} \ln \left(1 + \frac{P}{D}\right)$
(c) $t = \frac{1}{\lambda} \ln \left(1 + \frac{D}{P}\right)$ (d) $t = \frac{1}{\lambda} \ln \left(2 + \frac{P}{D}\right)$

43. A $^{235}_{92}U$ nucleus absorbs a neutron and forms $^{236}_{92}U$. This new nucleus is
(a) very stable and does not undergo any further nuclear reaction
(b) unstable and almost at once explodes into two fragments
(c) unstable and forms $^{239}_{94}Pu$
(d) unstable and the fragment product undergoes nuclear fusion

44. The mechanism of nuclear fission is explained on the basis of
(a) magic number of the nucleus (b) binding energy
(c) liquid-drop model (d) viscosity of the nucleus

45. As the mass number A increases, the binding energy per nucleon of the nucleus
(a) decreases
(b) varies in a way that depends upon the actual value of A

(c) remains unchanged
(d) increases

46. During a nuclear fission reaction,
(a) a heavy nucleus bombarded by thermal neutrons, splits
(b) two light nuclei combine to give a heavier nucleus
(c) a heavy nucleus splits into two fragments by itself
(d) a light nucleus bombarded by thermal neutrons, splits

47. Two deuterium nuclei in a deuterium vapour state at room temperature do not combine to form a helium nucleus because
(a) He^{2+} nucleus is unstable
(b) coulombic repulsion does not allow the nuclei to come close together
(c) a deuterium nucleus is more tightly bound than a helium nucleus
(d) it is not energetically favourable

48. A heavy nucleus has larger N/Z ratio because
(a) a neutron has large mass compared to a proton and an electron
(b) mean life of neutron is greater than that of a proton
(c) a neutron exerts electric repulsion
(d) the nucleus has larger number of neutrons

49. During nuclear fission, the final state has lesser energy than the reactant. The nuclear reaction takes place even though intermediate state has greater energy than the initial one and no energy is supplied externally. This process is called
(a) barrier penetration
(b) tunnelling
(c) formation of compound nucleus
(d) binding energy

50. The fission fragments reduce their N/Z ratio further via
(a) positive beta decay (b) negative beta decay
(c) alpha decay (d) gamma decay

51. As fission fragments decay
(a) it gives rise to stable heavy nucleus
(b) it gives light nuclei with an emission of energy
(c) an additional energy in the form of kinetic energy of β-particles, antinutrino and photons are released
(d) an additional energy is absorbed and then it decays to give β and γ-rays

52. Which of the following nuclei will absorb fast neutron having energy range 1–100 eV?

Given, fast neutron (energy ≈ 2 MeV) and slow neutron (energy ≈ 0.04 eV).

(a) ^{235}U (b) ^{238}U

(c) ^{233}U (d) $^{2}_{1}H$

53. In a fission reaction, when the rate of loss of neutron is increased fast, the chain reaction stops. This can be done by using a metal moderator which is

(a) Be (b) Zn

(c) Cd (d) carbon rod

54. In sun and other stars, where temperature is about 10^7 K, fusion takes place dominantly by

(a) proton-nitrogen cycle (b) proton-proton cycle

(c) proton-deuterium cycle (d) proton-lithium cycle

55. When the temperature inside the star increases, it produces $^{12}C + \gamma$. The process can continue to produce stable

(a) Fe(A = 56) (b) N(A = 14)

(c) Zn(A = 65) (d) U(A = 238)

56. Two nuclei moving towards each other may come close enough (overcoming coulombic repulsion and temperature of about 10^8 K) to fuse into one nucleus is known as

(a) thermonuclear fission (b) nuclear fusion

(c) breeder reaction (d) positron emission

57. In hotter stars, where the temperature is about 10^8 K, fusion takes place and the cycle is known as

(a) proton-carbon cycle (b) proton-neutron cycle

(c) carbon-deuterium cycle (d) nitrogen-oxygen cycle

58. On which of the following factors the principle of radiocarbon dating is based?

(a) The radioactive ^{14}C content of a sample of dead animal or plant tissue decreases steadily, while its ^{12}C content remains unchanged. Hence the ratio of ^{14}C to ^{12}C of the sample indicates that elapsed since the death of the organism.

(b) The rate of disintegration of ^{14}C is faster than ^{12}C.

(c) The ratio of ^{14}C to ^{12}C is not a fixed quantity.

(d) ^{14}C is radioactive and ^{12}C is non-radioactive.

• *Type 2* •

Choose the correct options. More than one option is correct.

59. Which of the following is used as a moderator in a nuclear reactor?

(a) Heavy water (b) Graphite

(c) Beryllium (d) Sodium

60. Which of the following statements is correct?

(a) ^{238}U has only a small cross section for the capture of slow neutron

(b) ^{235}U has a very large cross section for the capture of slow neutron

(c) Neutrons are accelerated by the moderators

(c) All of these

61. When fission occurs, several neutrons are released and the fission fragments are beta radioactive because

(a) the neutron/proton ratio required for stability, decreases with increasing A

(b) some of the excess neutrons are released directly

(c) some of the neutrons change to proton by beta decay in the fission fragments

(d) all of these

62. Which of the following statments is correct?

(a) Radiocarbon is produced by the cosmic rays following the nuclear reaction ^{14}N(n, p)

(b) All living things do not contain radiocarbon

(c) The proportion of radiocarbon in living matter is constant but decreases after death, which permits the remains to be dated

(d) All of these

63. In the decay process

$$A \xrightarrow{-\alpha} B \xrightarrow{-\beta} C \xrightarrow{-\beta} D$$

(a) A and B are isobars (b) A and D are isotopes

(c) B, C and D are isobars (d) A and C are isotones

64. Which of the following are β^--emitters?

(a) Carbon-14 (b) Cobalt-60

(c) Tritium-3 (d) Free neutron

65. Which of the following are α-emitters?

(a) Polonium-212 (b) Radium-226

(c) Helium-5 (d) Tritium

66. Which of the following do not occur?

(a) ${}^{40}_{20}\text{Ca} + {}^{1}_{0}\text{n} \rightarrow {}^{40}_{19}\text{K} + {}^{1}_{1}\text{H}$

(b) ${}^{24}_{12}\text{Mg} + {}^{4}_{2}\text{He} \rightarrow {}^{27}_{14}\text{Si} + {}^{1}_{0}\text{n}$

(c) ${}^{113}_{48}\text{Cd} + {}^{1}_{0}\text{n} \rightarrow {}^{112}_{48}\text{Cd} + {}^{0}_{-1}\text{e}$

(d) ${}^{43}_{20}\text{Ca} + {}^{4}_{2}\text{He} \rightarrow {}^{46}_{21}\text{Sc} + {}^{1}_{1}\text{H}$

67. Which of the following make up an isotonic triad?

(a) ${}^{14}_{6}\text{C}$, ${}^{16}_{8}\text{O}$, ${}^{15}_{7}\text{N}$

(b) ${}^{76}_{32}\text{Ge}$, ${}^{77}_{33}\text{As}$, ${}^{75}_{31}\text{Ga}$

(c) ${}^{40}_{18}\text{Ar}$, ${}^{40}_{19}\text{K}$, ${}^{40}_{20}\text{Ca}$

(d) ${}^{233}_{92}\text{U}$, ${}^{232}_{90}\text{Th}$, ${}^{239}_{94}\text{Pu}$

68. Stable nuclides cannot be obtained for

(a) $Z = 43, N = 35$

(b) $Z = 61, N = 89$

(c) $A = 8$ or 5

(d) $A > 209$

69. Which of the following processes are feasible?

(a) ${}^{1}_{0}\text{n} \rightarrow {}^{1}_{1}\text{p} + {}^{0}_{1}\text{e} + \overline{\nu}$

(b) ${}^{1}_{1}\text{p} \rightarrow {}^{1}_{0}\text{n} + {}^{0}_{+1}\text{e} + \nu$

(c) ${}^{1}_{1}\text{H} + {}^{0}_{-1}\text{e} \rightarrow {}^{1}_{0}\text{n}$

(d) ${}^{1}_{1}\text{p} + {}^{1}_{0}\text{n} \rightarrow {}^{2}_{1}\text{D} + \nu$

70. Which of the following nuclei are stable?

(a) ${}^{60}_{28}\text{Ni}$

(b) ${}^{11}_{6}\text{C}$

(c) ${}^{7}_{3}\text{Li}$

(d) ${}^{8}_{4}\text{Be}$

71. A nuclide has mass number A and atomic number Z. During a radioactive process, if

(a) both A and Z decrease, the process is called α-decay

(b) A remains unchanged and Z decreases by one, the process is called β^+-decay or K-electron capture

(c) both A and Z remain unchanged, the process is called γ-decay

(d) both A and Z increase, the process is called nuclear isomerism

72. Which of the following nuclei are doubly magic?

(a) ${}^{4}_{2}\text{He}$

(b) ${}^{16}_{8}\text{O}$

(c) ${}^{208}_{82}\text{Pb}$

(d) ${}^{238}_{92}\text{U}$

73. A nuclide X undergoes α-decay and another nuclide Y, β^- decay. Which of the following statements are correct?

(a) The β-particles emitted by Y may have widely different speeds.

(b) The α-particles emitted by X may have widely different speeds.

(c) The α-particles emitted by X will have almost the same speed.

(d) The β-particles emitted by Y will have the same speed.

74. Which of the following statements is correct?

(a) When an electron is emitted by an atom and its nucleus gets de-excited as a result, the process is called internal conversion.

(b) Pair production is a process which involves the creation of a positron-electron pair by a photon of energy 1.02 MeV.

(c) Neutrons are emitted in the electron-capture process.

(d) Electron capture and β^+-emission are identical processes.

75. Which of the following statements are correct?

(a) In many α- and β-decay processes, γ-radiation is emitted.

(b) The nuclear isomers produced by γ-ray bombardment have the same atomic and mass number but differ in their life-times (except that the ground states may be stable).

(c) The wavelength and absolute magnitude of the difference between the spins of the initial and final states are the same for γ- and X-rays.

(d) A nucleus in an excited state may give up its excitation energy and return to the ground state by the emission of electromagnetic γ-radiation.

Answers

1. d	**2.** b	**3.** b	**4.** a	**5.** b
6. b	**7.** b	**8.** c	**9.** c	**10.** c
11. b	**12.** b	**13.** b	**14.** c	**15.** b
16. a	**17.** b	**18.** b	**19.** c	**20.** a
21. a	**22.** c	**23.** c	**24.** b	**25.** d
26. c	**27.** b	**28.** a	**29.** d	**30.** b
31. a	**32.** b	**33.** d	**34.** a	**35.** c
36. c	**37.** d	**38.** a	**39.** a	**40.** b
41. a	**42.** c	**43.** b	**44.** c	**45.** b
46. a	**47.** b	**48.** d	**49.** a	**50.** b
51. c	**52.** b	**53.** c	**54.** b	**55.** a
56. b	**57.** a	**58.** a	**59.** a, b, c	**60.** a, b
61. b, c	**62.** a, c	**63.** b, c	**64.** a, b, c, d	**65.** a, b
66. c, d	**67.** a, b	**68.** a, b, c, d	**69.** a, b	**70.** a, c
71. a, b, c	**72.** a, b, c	**73.** a, c	**74.** a, b, d	**75.** a, b, c, d

Hints to More Difficult Problems

2. $^{232}_{92}X \rightarrow {}^{220}_{89}Y + x\,{}^{4}_{2}He^{2+} + y - {}^{0}_{-1}e.$

Equating the mass numbers on both sides of the equation, we get

$$232 = 220 + 4x + y \Rightarrow x = 3.$$

Equating the atomic numbers on both sides of the equation, we have

$$92 = 89 + 2x - y = 89 + 2 \times 3 - y = 89 + 6 - y \Rightarrow y = 3.$$

Thus, three α and three β-particles are emitted.

3. $^{A}_{Z}X \rightarrow {}_{Z+1}{}^{A}Y + {}^{0}_{-1}e(\beta^-),\ {}_{Z+1}{}^{A}Y \rightarrow {}^{A-4}_{Z-1}Z + {}^{4}_{2}He^{2+}(\alpha)$ and $^{A-4}_{Z-1}Z \rightarrow {}^{A-4}_{Z-1}Z + \gamma$

Therefore, the sequence of radiation is β, α, γ.

8. It may be stated that

$^{a}_{c}X \rightarrow {}^{b}_{d}Y + x\,{}^{4}_{2}He + y\,{}^{0}_{-1}e$

where x = no. of α-particles emitted

and y = no. of β-particles emitted.

$$a = b + 4x \quad \text{or} \quad x = \frac{a-b}{4} \qquad (1)$$

and $c = d + 2x - y.$ (2)

Substituting the value of x from Equation (1) in Equation (2), we get

$$c = d + \left(\frac{a-b}{4}\right)2 - y$$

$$\therefore \quad y = \text{no. of } \beta\text{-particles emitted} = d + \left[\frac{a-b}{2}\right] - c$$

9. During γ-radiation, the mass number and atomic number remain unchanged. So the nuclide remains neutral.

13. $^{29}_{13}Al \longrightarrow {}^{29}_{14}Si + {}^{0}_{-1}e$

$N/Z = \frac{16}{13} = 1.23$ $\qquad$ $N/Z = \frac{15}{14} = 1.07$ (required for stability)

15. The N/Z ratio in option (b) is not conductive to stability.

19. $^{219}_{84}Rn$ and $^{235}_{92}U$ belong to the $4n + 3$ series.

21. Given $\frac{Pb}{U} = 0.25 \Rightarrow 1 + \frac{Pb}{U} = 1 + 0.25 \Rightarrow \frac{U + Pb}{U} = 1.25$ or $\frac{N_0}{N} = 1.25 = \frac{5}{4}.$

$$t = \frac{2.303}{\lambda}\log\frac{N_0}{N}\ \text{y and } \lambda = \frac{0.693}{t_{1/2}} = \frac{0.693}{4 \times 10^9}\ \text{y}^{-1}.$$

$$\therefore \quad t = \frac{2.303}{0.693}(4 \times 10^9)\left(\log\frac{5}{4}\right)\text{y}.$$

24. $t_{1/2} = \dfrac{\ln 2}{\lambda} = T \ln 2 \qquad \left[T = \dfrac{1}{\lambda}\right].$ (1)

Given, $t = 4t_{1/2} \Rightarrow t_{1/2} = \dfrac{t}{4}$. (2)

From Equations (1) and (2),

$$\frac{t}{4} = T \ln 2 \Rightarrow t = 4T \ln 2.$$

25. We know that $t = t_{1/2} \dfrac{\ln (N_0/N)}{\ln 2}$.

$$t = 2\,\frac{\ln 64}{\ln 2} = 2\,\frac{\ln 2^6}{\ln 2} = 12 \text{ hrs.}$$

26. Activity $= \lambda N$.

$$6.02 \times 3.7 \times 10^{10} = 3.7 \times 10^{4}\,\frac{m}{100} \times 6.02 \times 10^{23} \Rightarrow m = 1 \times 10^{15} \text{ g.}$$

27. We know that $t = t_{1/2} \dfrac{\ln (N_0/N)}{\ln 2}$.

$$n = 2n\,\frac{\ln (N_0/N)}{\ln 2} \Rightarrow \ln 2 = \ln\left(\frac{N_0}{N}\right)^2 \Rightarrow \frac{N_0}{N} = \sqrt{2} \Rightarrow \frac{N}{N_0} = \frac{1}{\sqrt{2}}$$

29. Using $t = t_{1/2} \dfrac{\ln (N_0/N)}{\ln 2}$, we get

$$12 = 3\,\frac{\ln (N_0/N)}{\ln 2} \Rightarrow 4 \ln 2 = \ln (N_0/N)$$

$$\Rightarrow \frac{N_0}{N} = 2^4 \Rightarrow N_0 = 2^4 N = 2^4 \times 3 = 48 \text{ g.}$$

30. Let R_0 = initial activity.

Then $R_1 = R_0 e^{-\lambda t_1}$ and $R_2 = R_0 e^{-\lambda t_2}$ for state 2.

$$\frac{R_2}{R_1} = \frac{e^{-\lambda t_2}}{e^{-\lambda t_1}} = e^{\lambda(t_1 - t_2)} = e^{(t_1 - t_2)/T} \qquad \left[\lambda = \frac{1}{T}\right]$$

or $R_2 = R_1\, e^{(t_1 - t_2)/T}$.

$\therefore\ T = (t_1 - t_2)/\ln (R_2/R_1)$.

31. Initial count rate for 1 mL of liquid $= \dfrac{x}{200}$.

After 4 half-lives,

count rate for 1 mL of liquid $= \dfrac{1}{2^4} \times \dfrac{x}{200}$.

Let the volume of the remaining liquid = V mL.

$\therefore$ count rate of this liquid $V \times \dfrac{x}{2^4 \times 200} = \dfrac{x}{20}$

or $V = 160$ mL

33. Using the equation

$$P = E\left(\frac{dN}{dt}\right),$$

where P = power

and E = energy

$$\left|\frac{dN}{dt}\right| = \lambda N,$$

we get

$$P = 0.34 \times 10^{6} \times 1.6 \times 10^{-19} \times \frac{0.693}{5 \times 86400} \times \frac{4 \times 10^{-3}}{210} \times 6.02 \times 10^{23}$$

$$= 1 \text{ W}. \qquad (1 \text{ day} = 86{,}400 \text{ s})$$

34. Equal fractions decay in equal periods of time.
Therefore, if a fraction 0.8 remains undecayed after 1 day, a fraction $(0.8)^2 = 0.64$ will remain undecayed after 2 days.

35. Using the equation for secular equilibrium, $\lambda_1 N_1 = \lambda_2 N_2$, where the subscript 1 corresponds to ^{238}U and 2 to ^{226}Ra, we get

$$N_2 = \frac{\lambda_1}{\lambda_2} N_1 \Rightarrow \frac{m_2}{226} \times 6.02 \times 10^{23} = \frac{\dfrac{0.693}{4.5 \times 10^{9}}}{\dfrac{0.693}{1.6 \times 10^{3}}} \times \frac{m_1}{238} \times 6.02 \times 10^{23}.$$

$$\frac{m_2}{m_1} = \frac{1.6 \times 10^{3}}{4.5 \times 10^{9}} \times \frac{226}{238} = 3.4 \times 10^{-7}.$$

37. During electron capture, the proton in the nucleus captures an electron from the K shell, creating a vacancy. This vacancy is filled by the electron in the L shell, with the emission of X-rays.

42. $N = N_0 e^{-\lambda t}$,
where N = parent remaining = P
and N_0 = parent + daughter = $P + D$.

$$P = (P + D)e^{-\lambda t}$$

$$\frac{P}{P + D} = e^{-\lambda t} \Rightarrow \ln\frac{P + D}{P} = \lambda t$$

$$\Rightarrow t = \frac{1}{\lambda}\ln\left(1 + \frac{D}{P}\right).$$

43. Forms energetic compound nucleus

44. Greater cross-section area

49. Based on "Mass defects" and "Binding energy"

54. Cadmium is a good neutron absorber

63. *Example*

$$^{232}_{90}\mathrm{Th} \xrightarrow{-\alpha\left(^{4}_{2}\mathrm{He}^{2+}\right)} {}^{228}_{88}\mathrm{Ra} \xrightarrow{-\beta\left(^{0}_{-1}\mathrm{e}\right)} {}^{228}_{89}\mathrm{Ac} \xrightarrow{-\beta\left(^{0}_{-1}\mathrm{e}\right)} {}^{228}_{90}\mathrm{Th}$$

The emission of one α- and two β-particles produces isotopes (A and D).
The emission of n β-particles produces isobars (B, C and D).

65. Usually when $A > 209$ and $Z > 83$, the nucleus is an α-emitter.

67. All the nuclei in (a) have 8 neutrons and in (b) 44 neutrons.

72. The magic numbers of nuclides are 2, 8, 20, 28, 50, 82 and 126 (for either N or Z, or both N and Z).

$^{4}_{2}\mathrm{He}(N = 2, Z = 2)$, $^{16}_{8}\mathrm{O}(N = 8, Z = 8)$ and $^{208}_{82}\mathrm{Pb}(N = 126, Z = 82)$ are doubly magic.

❑

3

Chemical Bonding

• Type 1 •

Choose the correct option. Only one option is correct.

1. An ionic bond can be formed between two atoms when
(a) one of them has a low ionization energy and the other a high electron affinity
(b) both the atoms have low values of ionization energy
(c) both the atoms have high values of ionization energy
(d) both the atoms have low values of electron affinity

2. Which of the following is required for the formation of an ionic bond?
(a) An electron from the more electronegative element should be transferred to the less electronegative element.
(b) The total energy of the resulting molecule should be less than the total energy of the reactants.
(c) The lattice energy of the resultant molecule should be as low as possible.
(d) The ionic potentials of the reactants should be identical.

3. The cohesive energy of an ionic crystal is the energy
(a) liberated during its formation from individual neutral atoms
(b) absorbed during its formation from individual neutral atoms
(c) liberated during the formation of positive ions
(d) absorbed during the formation of negative ions

4. Among the following compounds, which has the maximum number of sp-hybridized C atoms?
(a) $(CN)_2$
(b) $CH{=}C{=}CH{-}CN$

(c) $HC\equiv C-CH_2CH_2=C=C=CH_2$
(d) $HC\equiv C-CN$

5. Which of the following statements is incorrect?
(a) NH_3 is more basic than PH_3.
(b) NH_3 has a higher boiling point than that of HF.
(c) N_2 is more inert than P_4.
(d) The dipole moment of NH_3 is less than that of SO_2.

6. An ionic solid is a poor conductor of electricity because
(a) ions do not conduct electricity
(b) the charge on the ions is uniformly distributed
(c) ions occupy fixed positions in solids
(d) ions have uniform fields of influence

7. According to Fajans' rules, ionic bonds are formed when cations have
(a) low positive charge and large size
(b) low positive charge and small size
(c) high positive charge and large size, and anions have a small size
(d) a low positive charge and large size, and anions have a small size

8. A covalent bond is formed between two atoms when
(a) one or more pairs of electrons are shared by the two atoms
(b) the two atoms are of the same size
(c) the electronegativities of the two atoms differ considerably
(d) the electron affinities of the two atoms are the same

9. What conclusions can be drawn from the following reactions?

$$H_2 + 4.5\text{ eV} \longrightarrow H + H$$
$$H + 13.6\text{ eV} \longrightarrow p^+ + e^-$$

(a) It is more difficult to break up an H_2 molecule than it is to break up a hydrogen atom.
(b) It is easier to break up an H_2 molecule than it is to break up a hydrogen atom.
(c) The average energy of formation of H and p^+ are the same.
(d) Electron and proton attraction in an H_2 molecule as well as an H atom are the same.

10. In an H_2^+ ion
(a) one electron is bound to two protons
(b) two electrons are bound to two protons
(c) three electrons are bound to two protons
(d) none of these happens

11. $AlCl_3$ is covalent while AlF_3 is ionic. This can be justified on the basis of
(a) the valence-bond theory
(b) Fajans' rules
(c) the molecular-orbital theory
(d) hydration energy

12. Among of the following molecules, which is the most ionic?
(a) $CaCl_2$ (b) $SnCl_2$ (c) NaCl (d) CuCl

13. Among the following, which has maximum hardness?
(a) NaF (b) Al_2O_3 (c) MgF_2 (d) TiO_2

14. Which of the following has the highest bond energy?
(a) F_2 (b) Cl_2 (c) Br_2 (d) I_2

15. Which of the following pairs have nearly identical values of bond energy?
(a) O_2 and H_2 (b) N_2 and CO (c) F_2 and I_2 (d) O_2 and Cl_2

16. The types of bonds present in $CuSO_4 \cdot 5H_2O$ are
(a) electrovalent and covalent
(b) electrovalent and coordinate covalent
(c) electrovalent, covalent, coordinate covalent and hydrogen bonds
(d) covalent and coordinate covalent

17. Which of the following is the most ionic?
(a) P_4O_{10} (b) MnO
(c) CrO_3 (d) Mn_2O_7

18. Among LiCl, $BeCl_2$, BCl_3 and CCl_4, the covalent bond character varies as
(a) $LiCl < BeCl_2 > BCl_3 > CCl_4$
(b) $LiCl > BeCl_2 < BCl_3 < CCl_4$
(c) $LiCl < BeCl_2 < BCl_3 < CCl_4$
(d) $LiCl > BeCl_2 > BCl_3 > CCl_4$

19. Among LiCl, $BeCl_2$, NaCl, CsCl, the compounds with the greatest and the least ionic character respectively are
(a) LiCl and CsCl (b) NaCl and LiCl
(c) CsCl and NaCl (d) CsCl and $BeCl_2$

20. The overlapping powers (overlap integrals) of 2s, 2p, $2sp^2$, $2sp^3$ and 2sp orbitals are in the order
(a) $2s > 2p > 2sp^3 > 2sp^2 > 2sp$ (b) $2p > 2s > 2sp^3 > 2sp^2 > 2sp$
(c) $2sp^3 > 2sp^2 > 2sp > 2s > 2p$ (d) $2sp^3 > 2sp^2 > 2sp > 2p > 2s$

21. Among the following species, which has the maximum number of resonating structures?

(a) PO_4^{3-} (b) SO_4^{2-}

(c) AsO_3^{3-} (d) MnO_4^{-}

22. According to Fajans' rules, covalent bond formation is favoured when there is a

(a) large cation and a small anion

(b) large cation and a large anion

(c) small cation and a small anion

(d) small cation and a large anion

23. Phosphorus shows a maximum covalency of

(a) five (b) seven

(c) six (d) three

24. Among the following, which have resonating structures?

(a) BF_3 (b) PCl_5

(c) SF_6 (d) IF_7

25. Which of the following molecules form 2-electron 3-centred bonds?

(a) Al_2Cl_6 (b) Hg_2Cl_2 (c) B_2H_6 (d) BH_3

26. An atom of element A has 3 electrons in its outermost shell while one of element X has 6 electrons in its outermost shell. The formula of the compound formed by A and X is

(a) A_2X_4 (b) A_2X_3 (c) A_3X_2 (d) A_2X

27. In a metallic crystal the

(a) valence electrons remain within the fields of influence of their own kernels

(b) valence electrons constitute a sea of mobile electrons

(c) valence electrons are localized between the two kernels

(d) kernels as well as the electrons move rapidly

28. Polarization involves the distortion of the shape of an anion by an adjacently placed cation. In this context, which of the following statements is correct?

(a) Maximum polarization is brought about by a cation of high charge.

(b) Minimum polarization is brought about by a cation of low radius.

(c) A large cation is likely to bring about a high degree of polarization.

(d) The polarizing power of a cation is less than that of an anion.

29. The bonds present in N_2O_5 are
(a) only ionic
(b) covalent and coordinate
(c) only covalent
(d) covalent and ionic

30. An element X forms compounds of formula XCl_3, X_2O_5 and Mg_3X_2 but does not form XCl_5. X is
(a) aluminium
(b) phosphorus
(c) nitrogen
(d) boron

31. Anhydrous $AlCl_3$ is covalent but $AlCl_3{\cdot}6H_2O$ is ionic because
(a) $AlCl_3$ has a plane triangular structure
(b) the ionization energy of Al is very low
(c) the hydration energy of $AlCl_3$ is very high
(d) the hydration energy of $AlCl_3$ compensates for the high ionization energy of aluminium

32. The molecular sizes of ICl and Br_2 are nearly the same, but the boiling point of ICl is about 39°C higher than that of Br_2. This is because
(a) the bond energy of I—Cl is greater than that of Br—Br
(b) the ionization energy of iodine is less than that of bromine
(c) ICl is polar while Br_2 is nonpolar
(d) the size of iodine is greater than that of bromine

33. Which of the following oxyacids of sulphur contain no sulphur-sulphur (S—S) bonds?
(a) $H_2S_2O_4$
(b) $H_2S_2O_5$
(c) $H_2S_2O_7$
(d) $H_2S_2O_3$

34. Which of the following oxyacids of phosphorus are monoprotic (monobasic)?
(a) H_3PO_4
(b) H_3PO_3
(c) H_3PO_2
(d) $H_4P_2O_7$

35. Which of the following has greater bond length?
(a) P—O
(b) S—O
(c) Cl—O
(d) O=O

36. Among following alcohols, which has the lowest boiling point?
(a) *n*-Butyl alcohol
(b) Isobutyl alcohol
(c) sec. Butyl alcohol
(d) tert. Butyl alcohol

37. Which of the following has been arranged in order of increasing covalent character?
(a) $KCl < CaCl_2 < AlCl_3 < SnCl_4$
(b) $SnCl_4 < AlCl_3 < CaCl_2 < KCl$
(c) $AlCl_3 < CaCl_2 < KCl < SnCl_4$
(d) $CaCl_2 < SnCl_4 < KCl < AlCl_3$

38. Which of the following factors is the most responsible for increase in boiling point as we move from He to Xe?

(a) Decrease in ionization energy
(b) Increase in electronegativity
(c) Decrease in polarizability
(d) Increase in polarizability

39. In which of the following structures is the energy requirement maximum for the formation of a hydrogen bond?

(a) F—H----F (b) F—H----O
(c) O—H----O (d) O—H----N

40. Hydrogen bonding is exhibited by

(a) all substances containing H atoms
(b) molecules in which hydrogen is bonded to F, O or N
(c) molecules in which one hydrogen is bonded to F and the other is bonded to Cl
(d) all substances containing H and O atoms

41. When two ice cubes are pressed together, they join to form one cube. Which of the following forces helps hold them together?

(a) Hydrogen bond formation
(b) Van der Waals forces
(c) Covalent attraction
(d) Dipole interaction

42. The maximum possible number of hydrogen bonds in which a water molecule can participate is

(a) four (b) three (c) two (d) one

43. The density of water is greater than that of ice because of

(a) dipole-dipole interaction
(b) hydrogen bonding
(c) dipole–induced dipole interaction
(d) covalent bond formation

44. The following molecules have the same molecular weight. Which of them has the highest boiling point?

(a) $CH_3CH_2CO_2H$ (b) $CH_3CH_2CH_2CH_2OH$
(c) $CH_3CH_2—O—CH_2CH_3$ (d) $CH_3CH_2COCH_3$

45. Orthonitrophenol is steam volatile but paranitrophenol is not because

(a) orthonitrophenol has intramolecular hydrogen bonding while paranitrophenol has intermolecular hydrogen bonding

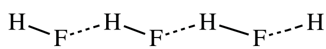
(b) both ortho- and paranitrophenol have intramolecular hydrogen bonding

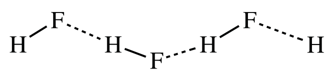
(c) orthonitrophenol has intermolecular hydrogen bonding and paranitrophenol has intramolecular hydrogen bonding

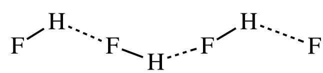
(d) Van der Waals forces are dominant in orthonitrophenol

46. The H bond in solid HF can be best represented as

(a) H—F····H—F····H—F

(b) 

(c) 

(d) 

47. For which of the following crystalline substances does the solubility in water increase upto 32°C and then decrease rapidly?

(a) $CaCl_2 \cdot 2H_2O$ (b) $Na_2SO_4 \cdot 10H_2O$

(c) $FeSO_4 \cdot 7H_2O$ (d) Alums

48. Which of the following is true?

(a) Bond order $\propto \dfrac{1}{\text{bond length}} \propto$ bond energy

(b) Bond order $\propto$ bond length $\propto \dfrac{1}{\text{bond energy}}$

(c) Bond order $\propto \dfrac{1}{\text{bond length}} \propto \dfrac{1}{\text{bond energy}}$

(d) Bond order $\propto$ bond length $\propto$ bond energy

49. Which of the following has been arranged in order of decreasing bond length?

(a) P—O > Cl—O > S—O (b) P—O > S—O > Cl—O

(c) S—O > Cl—O > P—O (d) Cl—O > S—O > P—O

50. During the formation of a molecular orbital from atomic orbitals, the electron density is

(a) minimum in the nodal plane

(b) maximum in the nodal plane

(c) zero in the nodal plane

(d) zero on the surface of the lobe

51. Which of the following represents correctly the order of filling of the molecular orbitals of B_2, C_2 and N_2?

(a) $\pi_{2p_x} = \pi_{2p_y} < \sigma_{2p_z} < \pi^*_{2p_y} = \pi^*_{2p_z} < \sigma^*_{2p_z}$

(b) $\sigma_{2p_z} < \pi_{2p_x} = \pi_{2p_y} < \pi^*_{2p_x} = \pi^*_{2p_y} < \sigma^*_{2p_z}$

(c) $\sigma_{2p_z} = \pi_{2p_x} = \pi_{2p_y} < \pi^*_{2p_x} = \pi^*_{2p_y} < \sigma^*_{2p_z}$

(d) $\pi_{2p_x} < \pi_{2p_y} < \sigma_{2p_z} > \pi_{2p_y} < \pi^*_{2p_z} = \sigma^*_{2p_z}$

52. The oxygen molecule is paramagnetic because

(a) the bonding electrons outnumber the antibonding electrons in the molecular orbital

(b) it contains unpaired electrons in the antibonding molecular orbitals

(c) it contains unpaired electrons in the bonding molecular orbitals

(d) the number of bonding electrons equals that of the antibonding electrons in the molecular orbitals

53. Which of the following have been arranged in increasing order of bond order as well as bond dissociation energy?

(a) $O_2^{-2} < O_2^- < O_2^+ < O_2$ (b) $O_2^{-2} < O_2^- < O_2 < O_2^+$

(c) $O_2 < O_2^+ < O_2^{2-} < O_2^-$ (d) $O_2^+ < O_2^{2-} < O_2^- < O_2$

54. Which of the following statements are not correct?

(a) Hybridization is the mixing of atomic orbitals.

(b) sp^2-hybrid orbitals are formed from two p-atomic orbitals and one s-atomic orbital.

(c) dsp^2-hybrid orbitals are all at 90° to one another.

(d) d^2sp^3-hybrid orbitals are directed towards the corners of a regular octahedron.

55. Which of the following has a pyramidal shape?

(a) PCl_3 (b) SO_3 (c) CO_3^{-2} (d) NO_3^-

56. The compound in which carbon uses its sp^3-hybrid orbitals for bond formation is

(a) HCO_2H (b) $(H_2N)_2CO$

(c) HCHO (d) CH_3CHO

57. The hybridization of carbon involved in the C—C single bond in the molecule $CH \equiv C-CH=CH_2$ is

(a) $sp^3–sp^2$ (b) $sp^3–sp^3$

(c) $sp–sp^2$ (d) $sp^2–sp^2$

58. Which of the following has been arranged in increasing order of size of the hybrid orbitals?

(a) $sp < sp^2 < sp^3$ (b) $sp^3 < sp^2 < sp$

(c) $sp^2 < sp^3 < sp$ (d) $sp^2 < sp < sp^3$

59. The silver atom in $AgCl_2^-$ is

(a) sp^3-hybridized (b) sp^2-hybridized

(c) sp-hybridized (d) unhybridized

60. The shapes of PCl_4^+, PCl_4^- and $AsCl_5$ are respectively

(a) square planar, tetrahedral and see-saw

(b) tetrahedral, see-saw and trigonal bipyramidal

(c) tetrahedral, square planar and pentagonal bipyramidal

(d) trigonal bipyramidal, tetrahedral and square pyramidal

61. Among the following, the molecule that is linear is

(a) CO_2 (b) NO_2 (c) SO_2 (d) ClO_2

62. CO_2 is not isostructural with

(a) $HgCl_2$ (b) $SnCl_2$ (c) C_2H_2 (d) $ZnCl_2$

63. If a molecule MX_3 has zero dipole moment, the sigma bonding orbitals used by M (atomic number < 21) are

(a) pure p (b) sp hybrid

(c) sp^2 hybrid (d) sp^3 hybrid

64. In the context of carbon, which of the following is arranged in the correct order of electronegativity.

(a) $sp > sp^2 > sp^3$ (b) $sp^3 > sp^2 > sp$

(c) $sp^2 > sp > sp^3$ (d) $sp^3 > sp > sp^2$

65. PCl_5 undergoes

(a) $sp^3 d_{z^2}$-hybridization (b) $sp^3 d_{x^2-y^2}$-hybridization

(c) $sp^3 d_{xy}$-hybridization (d) $sp^3 d_{yz}$-hybridization

66. When 2s-2s, 2p-2p and 2p-2s orbitals overlap, the bond strength decreases in the order

(a) p–p > s–s > p–s (b) p–p > p–s > s–s

(c) s–s > p–p > p–s (d) s–s > p–s > p–p

67. The hybridization of carbon in graphite is

(a) $sp^2 - sp^2$ (b) $sp^2 - sp^2 + 2\pi$

(c) $sp^2 - sp^2 + \frac{\pi}{3}$ (d) $sp^2 - sp^3 + \frac{\pi}{2}$

68. Which of the following pairs of elements form oxide polyanions and polycations respectively?

(a) Si and Al (b) Cu and Si
(c) Al and B (d) Ti and As

69. Which of the following kinds of hybridization are possible in $>C{=}C{=}$?

(a) sp^2–sp^2 (b) sp^2–sp
(c) sp–sp^3 (d) sp–sp

70. The hybridized states of carbon in diamond, graphite and acetylene are in the order

(a) sp^3, sp, sp^2 (b) sp^3, sp^2, sp
(c) sp, sp^2, sp^3 (d) sp^2, sp^3, sp

71. Which of the following pairs are isostructural?

(a) CH_3^- and CH_3^+ (b) NH_4^+ and NH_3
(c) SO_4^{2-} and BF_4^- (d) NH_2^- and BeF_2

72. How many sigma and pi bonds are present in tetracyanoethylene?

(a) Nine σ and nine π (b) Five π and nine σ
(c) Nine σ and seven π (d) Eight σ and eight π

73. The shape of XeF_4 is

(a) tetrahedral (b) square planar
(c) pyramidal (d) nearly linear

74. The shape of $XeOF_4$ is

(a) square pyramidal (b) square antiprismatic
(c) distorted octahedral (d) pentagonal bipyramidal

75. The structure of XeO_2F_2 is

(a) plane triangular (b) trigonal bipyramidal
(c) square planar (d) tetrahedral

76. The Xe atom in $XeOF_2$ involves the hybridization

(a) sp^3 (b) sp^3d
(c) sp^3d^2 (d) sp^3d^3

77. The volatility of HF is low because of

(a) its low polarizability
(b) the weak dispersion interaction between the molecules
(c) its small molecular mass
(d) its strong hydrogen bonding

78. The shapes of IF_5 and IF_7 are respectively
- (a) tetragonal pyramidal and pentagonal bipyramidal
- (b) octahedral and pyramidal
- (c) trigonal bipyramidal and square antiprismatic
- (d) distorted square planar and distorted octahedral

79. The N—O—N bond angle is maximum in
- (a) NO_2^+
- (b) NO_2
- (c) NO_2^-
- (d) N_2O_3

80. Which of the following arrangements correctly represent a decreasing order of bond angles?
- (a) $NH_3 > PH_3 > AsH_3$
- (b) $NH_3 > H_2O > F_2O$
- (c) $NO_2^+ > NO_2^- > NO_2$
- (d) $CH_4 > NH_3 > H_2O$

81. Which of the following have dipole moment?
- (a) 1,4-dichlorobenzene
- (b) *cis*-1,2-dichloroethene
- (c) *trans*-1,2-dichloroethene
- (d) *trans*-1,2-dichloropentene

82. Which of the following has maximum dipole moment?
- (a) CCl_4
- (b) CH_3Cl
- (c) CH_2Cl_2
- (d) $CHCl_3$

83. The shapes of XeF_6, XeF_5^- and XeF_8^{2-} are
- (a) octahedral, trigonal bipyramidal and square planar
- (b) square pyramidal, pentagonal bipyramidal and octahedral
- (c) square planar, planar pentagonal and square antiprismatic
- (d) see-saw, T-shaped and square pyramidal

respectively.

84. Which of the following is the least polar?
- (a) HF
- (b) HBr
- (c) HI
- (d) HCl

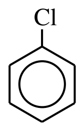
85. Which of the following has been arranged in order of decreasing dipole moment?
- (a) $CH_3Cl > CH_3F > CH_3Br > CH_3I$
- (b) $CH_3F > CH_3Cl > CH_3Br > CH_3I$
- (c) $CH_3Cl > CH_3Br > CH_3I > CH_3F$
- (d) $CH_3F > CH_3Cl > CH_3I > CH_3Br$

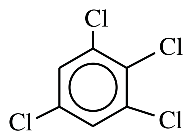
86. Which of the following has the least dipole moment?
- (a) NF_3
- (b) CO
- (c) SO_2
- (d) NH_3

87. The experimental value of the dipole moment of HCl is 1.03 D. The length of the H—Cl bond is 1.275 Å. The percentage of ionic character in HCl is

(a) 43 (b) 21

(c) 17 (d) 7

88. The dipole moment of  is 1.5 D.

The dipole moment of  is

(a) 0 D (b) 1.5 D (c) 2.86 D (d) 2.25 D

89. Which of the following pairs of structures are resonance forms?

(a) $:\ddot{\underset{..}{N}}-N\equiv N:$ and $:N=N=\underset{..}{N}:$

(b) $:\ddot{\underset{..}{N}}-N\equiv N:$ and $:\ddot{N}-N=\ddot{N}:$

(c) $:\ddot{\underset{..}{N}}-N\equiv N:$ and $:\ddot{\underset{..}{N}}-\ddot{\underset{..}{N}}-\ddot{\underset{..}{N}}:$

(d) All of these

90. Among the following structures, which is not a permissible resonance form?

(a) $\overset{+}{C}H_3-\underset{\underset{CH_3}{|}}{N}-\ddot{\underset{..}{O}}:^{-}$

(b) $CH_2=\underset{\underset{CH_3}{|}}{N}=\underset{..}{O}:$

(c) $CH_2=\underset{\underset{CH_3}{|}}{\overset{+}{N}}-\ddot{\underset{..}{O}}:^{-}$

(d) $:\overset{-}{C}H_3-\underset{\underset{CH_3}{|}}{\overset{+}{N}}=\underset{..}{O}:$

91. Which of the following molecules is the most polar?

(a) CH_3NH_2 (b) $(CH_3)_3CCl$

(c) CH_3NO_2 (d) $(CH_3)_3CH$

92. The I_3^- ion has

(a) five equatorial lone pairs on the central I atom and two axial bonding pairs in a trigonal bipyramidal arrangement

(b) five equatorial lone pairs on the central I atom and two axial bonding pairs in a pentagonal bipyramidal arrangement

(c) three equatorial lone pairs on the central I atom and two axial bonding pairs in a trigonal bipyramidal arrangement

(d) two equatorial lone pairs on the central I atom and three axial bonding pairs in a trigonal bipyramidal arrangement

93. Which of the following sets of characteristics leads to the increase in solubility of ionic substances?

(a) High dipole moment, strong attraction by an ion and large solvation energy

(b) Low dipole moment, weak attraction by an ion and high solvation energy

(c) High dipole moment, strong attraction by an ion and low solvation energy

(d) High dipole moment, weak attraction by an ion and large solvation energy

94. Among the following species, which has the minimum bond length?

(a) B_2 (b) C_2

(c) F_2 (d) O_2^-

95. $SnCl_4$ is a covalent liquid because

(a) electron clouds of the Cl^- ions are weakly polarized to envelop the cation

(b) electron clouds of the Cl^- ions are strongly polarized to envelop the cation

(c) its molecules are attracted to one another by strong van der Waals forces

(d) Sn shows inert-pair effect

96. The melting point of AlF_3 is 1040°C and that of SiF_4 is –77°C (it sublimes) because

(a) there is a very large difference in the ionic character of the Al—F and Si—F bonds

(b) in AlF_3, Al^{3+} interacts very strongly with the neighbouring F^- ions to give a three-dimensional structure but in SiF_4 no interaction is possible

(c) the silicon ion in the tetrahedral SiF_4 molecule is not shielded effectively from the fluoride ions whereas in AlF_3, the Al^{3+} ion is shielded on all sides

(d) the attractive forces between the SiF_4 molecules are strong whereas those between the AlF_3 molecules are weak

• *Type 2* •

Choose the correct options. More than one option is correct.

97. Most ionic compounds have

(a) high melting points and low boiling points

(b) high melting points and nondirectional bonds

(c) high solubilities in polar solvents and low solubilities in nonpolar solvents

(d) three-dimensional network structures, and are good conductors of electricity in the molten state

98. Which of the following substances are expected to be covalent?

(a) $BeCl_2$ (b) $SnCl_4$

(c) ZnS (d) $ZnCl_2$

99. Which of the following have a three-dimensional network structure?

(a) SiO_2 (b) $(BN)_x$

(c) P_4 (white) (d) CCl_4

100. To which of the following species is the octet rule not applicable?

(a) BrF_5 (b) SF_6

(c) IF_7 (d) CO

101. Which of the following do not exist?

(a) SH_6 (b) HFO_4

(c) FeI_3 (d) $HClO_3$

102. The species which contain an odd number of valence electrons and are paramagnetic are

(a) NO (b) NO_2

(c) ClO_2 (d) N_2O_4

103. Among the following, the elements which show inert-pair effect are

(a) Bi (b) Sn

(c) Pb (d) C

104. Which of the following have an (18 + 2)-electron configuration?

(a) Pb^{2+} (b) Cd^{2+} (c) Bi^{3+} (d) SO_4^{2-}

105. Which of the following species contain covalent coordinate bonds?

(a) $AlCl_3$ (b) CO (c) $[Fe(CN)_6]^{4-}$ (d) N_3^-

106. Which of the following oxyacids of sulphur contain S—S bonds?

(a) $H_2S_2O_8$ (b) $H_2S_2O_6$ (c) $H_2S_2O_4$ (d) H_2SO_5

107. Which of the following factors are responsible for van der Waals forces?

(a) Instantaneous dipole–induced dipole interaction

(b) Dipole–induced dipole interaction and ion–induced dipole interaction

(c) Dipole-dipole interaction and ion–induced dipole interaction

(d) Small size of molecule

108. Which of the following are true?

(a) Van der Waals forces are responsible for the formation of molecular crystals.

(b) Branching lowers the boiling points of isomeric organic compounds due to van der Waals forces of attraction.

(c) In graphite, van der Waals forces act between the carbon layers.

(d) In diamond, van der Waals forces act between the carbon layers.

109. Which of the following statements are correct?

(a) The crystal lattice of ice is mostly formed by covalent as well as hydrogen bonds.

(b) The density of water increases when heated from 0°C to 4°C due to the change in the structure of the cluster of water molecules.

(c) Above 4°C the thermal agitation of water molecules increases. Therefore, intermolecular distance increases and water starts expanding.

(d) The density of water increases from 0°C to a maximum at 4°C because the entropy of the system increases.

110. Intermolecular hydrogen bonding increases the enthalpy of vaporization of a liquid due to the

(a) decrease in the attraction between molecules

(b) increase in the attraction between molecules

(c) decrease in the molar mass of unassociated liquid molecules

(d) increase in the effective molar mass of hydrogen-bonded molecules

111. Which of the following molecules have intermolecular hydrogen bonds?

(a) KH_2PO_4 (b) H_3BO_3

(c) $C_6H_5CO_2H$ (d) CH_3OH

112. Intramolecular hydrogen bonds occur in

(a) 2-chlorophenol

(b) salicylic acid

(c) the enol form of acetylacetone

(d) paranitrophenol

113. Which of the following are diamagnetic?

(a) C_2 (b) O_2^{2-}

(c) Li_2 (d) N_2^+

114. Which of the following are paramagnetic?

(a) B_2 (b) O_2

(c) N_2 (d) He_2

115. Which of the following species have a bond order of 3?

(a) CO (b) CN^-

(c) NO^+ (d) O_2^+

116. Among the following, the species with one unpaired electron are

(a) O_2^+ (b) NO (c) O_2^- (d) B_2

117. Which of the following pairs have identical values of bond order?

(a) N_2^+ and O_2^+ (b) F_2 and Ne_2

(c) O_2 and B_2 (d) C_2 and N_2

118. Which of the following is correct?

(a) During N_2^+ formation, one electron each is removed from the bonding molecular orbitals.

(b) During O_2^+ formation, one electron each is removed from the antibonding molecular orbitals.

(c) During O_2^- formation, one electron each is added to the bonding molecular orbitals.

(d) During CN^- formation, one electron each is added to the bonding molecular orbitals.

119. Which of the following species are linear?

(a) ICl^{2-} (b) I^{3-}

(c) N_3^- (d) ClO_2

120. The structure of XeF_6 is

(a) pentagonal bipyramidal (b) distorted octahedral

(c) capped octahedral (d) square pyramidal

121. Which of the following have dipole moment?

(a) nitrobenzene (b) *p*-chloronitrobenzene

(c) *m*-dichlorobenzene (d) *o*-dichlorobenzene

Answers

1. a	**2.** b	**3.** a	**4.** d	**5.** b
6. c	**7.** d	**8.** a	**9.** b	**10.** a
11. b	**12.** c	**13.** b	**14.** b	**15.** c
16. c	**17.** b	**18.** c	**19.** d	**20.** d
21. b	**22.** d	**23.** c	**24.** a	**25.** c
26. b	**27.** b	**28.** a	**29.** b	**30.** c
31. d	**32.** c	**33.** c	**34.** c	**35.** a
36. d	**37.** a	**38.** d	**39.** b	**40.** b
41. a	**42.** a	**43.** b	**44.** a	**45.** a
46. c	**47.** b	**48.** a	**49.** b	**50.** c
51. a	**52.** b	**53.** b	**54.** c	**55.** a
56. d	**57.** c	**58.** a	**59.** c	**60.** b
61. a	**62.** b	**63.** c	**64.** a	**65.** a
66. b	**67.** c	**68.** a	**69.** b	**70.** b
71. c	**72.** a	**73.** b	**74.** a	**75.** b
76. b	**77.** c	**78.** a	**79.** a	**80.** a
81. b	**82.** b	**83.** c	**84.** c	**85.** a
86. b	**87.** c	**88.** b	**89.** a	**90.** b
91. c	**92.** c	**93.** a	**94.** b	**95.** b
96. b	**97.** a, b, c, d	**98.** a, b	**99.** a, b	**100.** a, b, c
101. a, b, c	**102.** a, b, c	**103.** a, b, c	**104.** a, c	**105.** b, c
106. b, c	**107.** a, b, c	**108.** a, b, c	**109.** a, b, c, d	**110.** b, d
111. a, b, c, d	**112.** a, b, c	**113.** a, b, c	**114.** a, b	**115.** a, b, c
116. a, b, c	**117.** a, c	**118.** a, b, d	**119.** a, b, c	**120.** b, c
121. a, b, c, d				

Hints to More Difficult Problems

1. A low ionization energy helps the formation of cations and a high electron affinity that of anions.

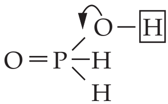
9. The energy required to form the hydrogen atom is greater than that required to form the H_2 molecule, as H_2 molecules are held by strong forces of attraction.

12. Among these pairs, the difference in electronegativity between Na and Cl atoms is the greatest.

17. The least charge on Mn favours ionic character.

18. Apply Fajans' rules (a large positive charge, and a small cation favour covalency).

23. Consider Sidgwick's covalency rule.

34.  (monoprotic acid)

37. Apply Fajans' rules.

40. Hydrogen bonding is facilitated by the high electronegativity and small size of the atoms concerned.

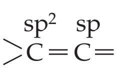
44. The tendency to form hydrogen bonds is greater in the —COOH group than in ethers, alcohols and ketones.

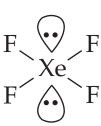
50. The amplitude of the wave function is zero, and hence the probability of finding an electron in the region concerned is almost zero.

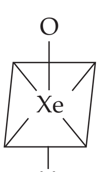
51. From considerations of energy

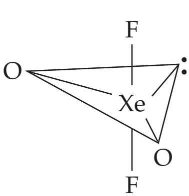
55. Ag has no unshared electrons.

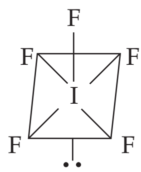
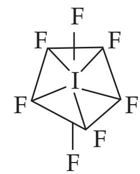
63. The molecule MX_3 has the general formula AX_3. The number of unshared electrons on M is zero and it is, therefore, sp^2-hybridized.

69. 

73. 

74. 

75. 

78.  

IF_5 (tetragonal pyramidal) IF_7 (pentagonal bipyramidal)

79. $O=\overset{+}{N}=O$

180°

(lp–lp > lp–bp > bp–bp) where lp stands for lone pair and bp for bond pair.

80. The increasing size and decreasing electronegativity of the central atom permit the bonding electrons to be drawn out further, thus decreasing repulsion between bonding pairs. This can also be seen by the energy difference i of the s and p orbitals of the central atoms.

84. The smallest difference in electronegativity is between H and I. One may also apply the H-annay and Smith equation

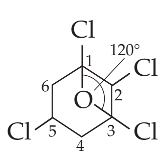
percentage of ionic character $= 16 \mid (X_A - X_B) \mid + 3.5, \mid (X_A - X_B) \mid$,

where $X_A - X_B$ is the electronegativity difference between the atoms.

87. $\mu_{cal} = e \times l = (4.802 \times 10^{-10}$ esu$)(1.275 \times 10^{-8}$ cm$)$

$= 6.12$ D (1 Debye $= 10^{-18}$ esu cm).

Percentage of ionic character $= \frac{\mu_{obs}}{\mu_{cal}} \times 100 = \frac{1.03}{6.12} \times 100 \approx 17$.

88. 

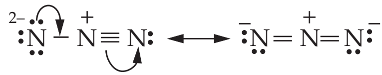
The μ's of 2Cl and 5Cl are vectorically cancelled.

$\mu^2 = \mu_1^2 + \mu_2^2 + 2\mu_1\mu_2 \cos\theta$

$= (1.5)^2 + (1.4)^2 + 2 \times 1.5 \times 1.5 \cos 120°$.

$\therefore \quad \mu = 1.5$ D.

89. The structures shown in option (a) are resonance forms, since they have the same atomic positions and the same number of electrons.

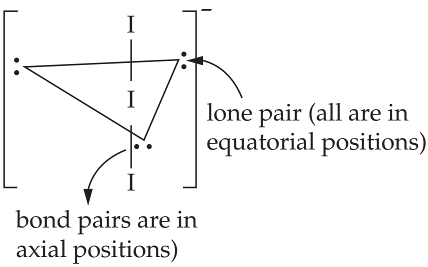


16 valence eletrons (net charge = – 1) 16 valence eletrons (net charge = – 1)

90. The structure shown in (b) has 10 electrons surrounding nitrogen, but the octet rule limits nitrogen to 8 electrons.

91. The Lewis structure of CH_3NO_2 has a formal charge of +1 on nitrogen, making it more electron-attracting than the other structures.

92.



94. Among the species, C_2 has the maximum bond order (=2) and the maximum bond energy.

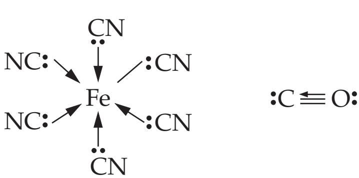
96. Structural factors

98. Apply Fajans' rules and also consider the effects of polarization.

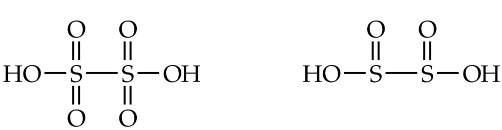
100. BrF_5 (14 electrons), SF_6 (12 electrons), IF_7 (14 electrons)

102. NO (5 + 6 = 11 valence electrons)
NO_2 (5 + 12 = 17 valence electrons)
ClO_2 (7 + 12 = 19 valence electrons)
All molecules have odd-electrons and are paramagnetic.

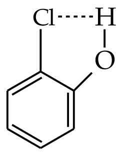
105.



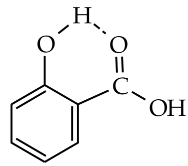
106.



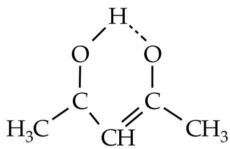
$H_2S_2O_6$ $H_2S_2O_4$

112. 

2-Chlorophenol



Salicylic acid



enol form of acetylacetone

(All molecules have intramolecular hydrogen bonds.)

113. From the molecular orbital theory, we know that these species have a bond order equal to zero. The number of unpaired electrons they possess is also zero. Hence they are diamagnetic.

114. From the molecular orbital theory, we know that B_2 and O_2 have two unpaired electrons each. Hence they are paramagnetic.

119. The species in options (a), (b) and (c) are sp-hybridized and are, therefore, linear.

❑

4

Gaseous State

• *Type 1* •

Choose the correct option. Only one option is correct.

1. A gas behaves like an ideal gas at

(a) high pressure and low temperature
(b) low pressure and high temperature
(c) high pressure and high temperature
(d) low pressure and low temperature

2. The energy of an ideal gas depends only on its

(a) pressure (b) volume
(c) number of moles (d) temperature

3. The quantity $pV/(k_BT)$ represents the

(a) number of molecules in the gas
(b) mass of the gas
(c) number of moles of the gas
(d) translation energy of the gas

4. The pressure p of a gas is plotted against its absolute temperature T for two different constant volumes, V_1 and V_2. When $V_1 > V_2$, the

(a) curves have the same slope and do not intersect
(b) curves must intersect at some point other than $T = 0$
(c) curve for V_2 has a lower slope than that for V_1
(d) curve for V_1 has a lower slope than that for V_2

5. Which of the following graphs is not a straight line for an ideal gas?

(a) $n \rightarrow T$ (b) $T \rightarrow p$ (c) $n \rightarrow \frac{1}{T}$ (d) $n \rightarrow \frac{1}{p}$

6. The density of nitrogen is maximum at

(a) stp (b) 273 K and 2 atm

(c) 546 K and 1 atm (d) 546 K and 4 atm

7. A closed vessel is maintained at a constant temperature. It is first evacuated, and then an ideal gas is introduced into it continuously. The pressure of the gas inside the vessel will

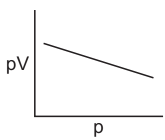
(a) remain constant

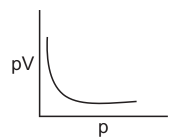
(b) first increase and then decrease

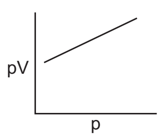
(c) first increase and then remain constant

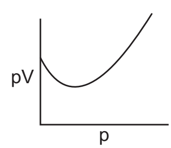
(d) make it burst after some time

8. Which of the following is a Boyle plot at very low pressure?

(a)


(b)


(c)


(d)


9. 1.0 litre of N_2 and $^7\!/_8$ litre of O_2 at the same temperature and pressure were mixed together. What is the relation between the masses of the two gases in the mixture?

(a) $M_{N_2} = 3M_{O_2}$ (b) $M_{N_2} = 8M_{O_2}$

(c) $M_{N_2} = M_{O_2}$ (d) $M_{N_2} = 16M_{O_2}$

10. The density of a gas A is twice that of a gas B at the same temperature. The molecular weight of gas B is thrice that of A. The ratio of the pressures acting on A and B will be

(a) 1 : 6 (b) 7 : 8 (c) 2 : 5 (d) 1 : 4

11. A volume V of a gas at a temperature T_1 and a pressure p is enclosed in a sphere. It is connected to another sphere of volume $V/2$ by a tube and stopcock. The second sphere is initially evacuated and the stopcock is closed. If the stopcock is opened the temperature of the gas in the second sphere becomes T_2. The first sphere is maintained at a temperature T_1. What is the final pressure p_1 within the apparatus?

(a) $\dfrac{2pT_2}{2T_2 + T_1}$ (b) $\dfrac{2pT_2}{T_2 + 2T_1}$ (c) $\dfrac{pT_2}{2T_2 + T_1}$ (d) $\dfrac{2pT_2}{T_1 + T_2}$

12. Two vessels A and B have volumes V and $4V$ respectively. Both vessels contain some water. The pressure in the space above water is p_1 for vessel A and p_2 for vessel B. What will be the relation between p_1 and p_2?

(a) $p_1 = 4p_2$ (b) $4p_1 = p_2$

(c) $p_1 = p_2$ (d) $p_1 = 16p_2$

13. Air contains 23% oxygen and 77% nitrogen by weight. The percentage of O_2 by volume is

(a) 28.1 (b) 20.7

(c) 21.8 (d) 23.0

14. To which of the following gaseous mixtures is Dalton's law not applicable?

(a) $Ne + He + SO_2$ (b) $NH_3 + HCl + HBr$

(c) $O_2 + N_2 + CO_2$ (d) $N_2 + H_2 + O_2$

15. A mixture contains N_2O_4 and NO_2 in the ratio $2:1$ by volume. The vapour density of the mixture is

(a) 45.4 (b) 49.8

(c) 32.6 (d) 38.3

16. An open vessel at 27°C is heated until $^3\!/_8$th of the air in it has been expelled. Assuming that the volume remains constant, calculate the temperature at which the vessel was heated.

(a) 307°C (b) 107°C

(c) 480°C (d) 207°C

17. If the density of liquid water is 1.0 g cm^{-3} and that of water vapour is 0.0006 cm^{-3} at 100°C and 1 atm, then the volume occupied by water molecules in 1 litre of steam at this temperature is

(a) 6 cm^3 (b) 60 cm^3

(c) 0.6 cm^3 (d) 0.06 cm^3

18. A gas has a density of 2.68 g L^{-1} at stp. Identify it.

(a) NO_2 (b) Kr (c) COS (d) SO_2

19. Given the reaction

$$C(s) + H_2O(l) \longrightarrow CO(g) + H_2(g)$$

calculate the volume of the gases produced at stp from 48.0 g of carbon.

(a) 179.2 L (b) 89.6 L

(c) 44.8 L (d) 22.4 L

20. Calculate the percentage of NO_2 by weight in N_2O_4 (a dimer of NO_2) which has a vapour density of 36.

(a) 27.7 (b) 67.7 (c) 37.7 (d) 25.7

21. A preweighed vessel was filled with CO_2 at stp and weighed. It was then evacuated, filled with SO_2 at the same temperature and pressure and again weighed. The weight of the CO_2 will be

(a) the same as that of the SO_2 (b) twice that of the SO_2

(c) half that of the SO_2 (d) one-fourth that of the SO_2

22. The vapour pressure of water at 80°C is 355 mm of Hg. A 100-mL vessel contains water saturated with O_2 at 80°C, the total pressure being 760 mm of Hg. The contents of the vessel were pumped into a 50-mL vessel at the same temperature. What is the partial pressure of O_2?

(a) 1115 mm (b) 810 mm

(c) 405 mm (d) 355 mm

23. A bottle of dry ammonia and one of dry hydrogen chloride are connected through a long tube. The stoppers at both ends of the tube are opened simultaneously. The white ammonium chloride ring first formed will be

(a) at the centre of the tube

(b) near the hydrogen chloride bottle

(c) near the ammonia bottle

(d) throughout the length of the tube

24. At stp, 0.48 g of O_2 diffused through a porous partition in 1200 seconds. What volume of CO_2 will diffuse in the same time and under the same conditions?

(a) 286.5 mL (b) 346.7 mL (c) 112.2 mL (d) 224.8 mL

25. At what temperature will the molar KE of 0.3 mol of He be the same as that of 0.4 mol of argon at 400 K?

(a) 700 K (b) 500 K (c) 800 K (d) 400 K

26. Indicate which of the following statements are correct.

(a) At constant temperature, the KE of all gas molecules is the same.

(b) At constant temperature, the KE of different molecules is different.

(c) At constant temperature, the KE is greater for heavier gas molecules.

(d) At constant temperature, the KE is less for heavier gas molecules.

27. The molecular velocities of two gases at the same temperature are u_1 and u_2 and their masses are m_1 and m_2 respectively. Which of the following expressions are correct?

(a) $\dfrac{m_1}{u_1^2} = \dfrac{m_2}{u_2^2}$ (b) $m_1u_1 = m_2u_2$

(c) $\dfrac{m_1}{u_1} = \dfrac{m_2}{u_2}$ (d) $m_1u_1^2 = m_2u_2^2$

28. The rms speed of N_2 molecules in a gas is u. If the temperature is doubled and the nitrogen molecules dissociate into nitrogen atoms, the rms speed becomes

(a) $u/2$ (b) $2u$
(c) $4u$ (d) $14u$

29. Consider a mixture of SO_2 and O_2 kept at room temperature. Compared to the oxygen molecule, the SO_2 molecule will hit the wall with

(a) smaller average speed (b) greater average speed
(c) greater kinetic energy (d) greater mass

30. The translational kinetic energy of an ideal gas depends only on its

(a) pressure (b) force
(c) temperature (d) molar mass

31. A bubble of gas released at the bottom of a lake increases to eight times its original volume when it reaches the surface. Assuming that atmospheric pressure is equivalent to the pressure exerted by a column of water 10 m high, what is the depth of the lake?

(a) 90 m (b) 10 m
(c) 70 m (d) 80 m

32. Choose the correct arrangement. The symbols have their usual meanings.

(a) $\overline{u} > u_p > u_{\text{rms}}$ (b) $u_{\text{rms}} > \overline{u} > u_p$
(c) $u_p > \overline{u} > u_{\text{rms}}$ (d) $u_p > u_{\text{rms}} > \overline{u}$

33. At what temperature is the rms speed of hydrogen molecules the same as that of oxygen molecules at 1327°C?

(a) 173 K (b) 100 K
(c) 400 K (d) 523 K

34. The compressibility of a gas is less than unity at stp. Therefore,

(a) $V_{\text{m}} > 22.4$ L (b) $V_{\text{m}} < 22.4$ L
(c) $V_{\text{m}} = 22.4$ L (d) $V_{\text{m}} = 44.8$ L

35. At low pressure, the van der Waals equation is reduced to

(a) $Z = \dfrac{pV_{\text{m}}}{RT} = 1 - \dfrac{ap}{RT}$ (b) $Z = \dfrac{pV_{\text{m}}}{RT} = 1 + \dfrac{b}{RT}p$
(c) $pV_{\text{m}} = RT$ (d) $Z = \dfrac{pV_{\text{m}}}{RT} = 1 - \dfrac{a}{RT}$

36. The temperature at which real gases obey the ideal gas laws over a wide range of pressures is called

(a) critical temperature (b) inversion temperature
(c) Boyle temperature (d) reduced temperature

37. However great the pressure, a gas cannot be liquefied above its

(a) Boyle temperature (b) inversion temperature

(c) critical temperature (d) room temperature

38. At high temperature and low pressure, the van der Waals equation is reduced to

(a) $\left(p+\frac{a}{V_\mathrm{m}^2}\right)(V_\mathrm{m})=RT$ (b) $pV_\mathrm{m}=RT$

(c) $p(V_\mathrm{m}-b)=RT$ (d) $\left(p+\frac{a}{V_\mathrm{m}^2}\right)(V_\mathrm{m}-b)=RT$

39. Real gases approach ideal gas behaviour at

(a) low temperature and low pressure

(b) low temperature and high pressure

(c) high temperature and high pressure

(d) high temperature and low pressure

40. In the corrections made to the ideal gas equation for red gases, the reduction in pressure due to attractive forces is directly proportional to

(a) n/V (b) nb

(c) n^2/V^2b (d) n^2/V^2

41. Consider the following gases and their corresponding values of *a* given in brackets.

CH_4(2.25), N_2(1.35), O_2(1.36) and CO(1.46)

Which of them will liquefy with great difficulty?

(a) CH_4 (b) N_2

(c) O_2 (d) CO

42. Generally, the greater the value of the van der Waals constant *b* of a gas, the greater is the size of its molecule. Which of the following is an exception to this rule?

(a) $H_2(b=0.0267)$ (b) $He(b=0.0241)$

(c) $CO_2(b=0.0427)$ (d) $Ne(b=0.0169)$

43. Consider the equation $Z=\frac{pV}{RT}\cdot$ Which of the following statements is correct?

(a) When Z > 1, real gases are easier to compress than the ideal gas.

(b) When Z = 1, real gases get compressed easily.

(c) When Z > 1, real gases are difficult to compress.

(d) When Z = 1, real gases are difficult to compress.

44. The van der Waals equation of state is

$$\left(p + \frac{a}{V^2}\right)(V - nb) = nRT.$$

The pressure exerted by individual gas molecules on the walls of the container depend on the

(a) frequency of the collisions of the molecules with the walls as well as the momentum imparted by the molecules to the walls.

(b) frequency of molecular collision

(c) mean free path of the molecules

(d) momentum and critical pressure of the gas molecules

45. Which of the following statements is incorrect?

(a) It is not possible to compress a gas at a temperature below T_c.

(b) At a temperature below T_c, the molecules are close enough for the attractive forces to act, and condensation occurs.

(c) No condensation takes place above T_c.

(d) The kinetic energy of the gas molecules is higher above T_c, and the attraction between them decreases.

46. The van der Waals equation for $n = 1$ mol may be expressed as

$$V_m^3 - \left(b + \frac{RT}{p}\right)V_n^2 + \frac{aV_n}{p} - \frac{ab}{p} = 0,$$

where V_m is the molar volume of the gas. Which of the following is correct?

(a) For a temperature less than T_c, V has three real roots.

(b) For a temperature less than T_c, V has one real and two imaginary roots.

(c) For a temperature equal to T_c all three roots of V are real and identical.

(d) All of these

47. At the critical point,

(a) $\left(\frac{\partial p}{\partial V_m}\right)_T = 1$ and $\left(\frac{\partial^2 p}{\partial V_m^2}\right)_T = 0$

(b) $\left(\frac{\partial p}{\partial V_m}\right)_T = 0$ and $\left(\frac{\partial^2 p}{\partial V_m^2}\right)_T = 0$

(c) $\left(\frac{\partial T}{\partial V_m}\right)_p = 0$ and $\left(\frac{\partial^2 T}{\partial V_m^2}\right)_p = 0$

(d) $\left(\frac{\partial p}{\partial V_m}\right)_T = 0$ and $\left(\frac{\partial p}{\partial V_m}\right)_T = 0$

where V_m is the molar volume of the gas.

48. The density of sea-water is 1.03 g cm^{-3} and that of freshwater 1.00 g cm^{-3}. The height of a seawater column and the pressure exerted by it can be

(a) 0.10 m and 0.1 atmosphere (b) 1.0 m and 1 atmosphere

(c) 10.0 m and 1.0 atmosphere (d) 12.0 m and 2 atmospheres

respectively.

49. Let p and p_s be the partial pressure and saturated partial pressure of water respectively. Then the relative humidity is given by

(a) $\frac{p_s + p}{p_s} \times 100$ (b) $\frac{p}{p_s} \times 100$

(c) $\frac{p_s}{p} \times 100$ (d) $(p + p_s) \times 100$

50. Which of the following statements is correct?

(a) In effusion, molecular flux is directly proportional to molecular speed and inversely proportional to the square root of the molecular mass.

(b) In diffusion as well as effusion, ΔS (change in entropy) tends to become minimum.

(c) In effusion, molecular flux as well as molecular speed are inversely proportional to the square root of molecular mass.

(d) All of these

51. At Boyle temperature,

(a) the effects of the repulsive and attractive intermolecular forces just offset each other

(b) the repulsive intermolecular forces are greater than the attractive intermolecular forces

(c) the repulsive intermolecular forces are less than the attractive intermolecular forces

(d) $b - \frac{a}{RT} > 0$

• Type 2 •

Choose the correct option. More than one option is correct.

52. Which of the following quantities is the same for all ideal gases at the same temperature?

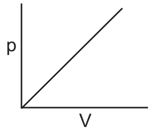
(a) The kinetic energy of 1 mol

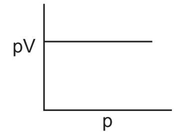
(b) The kinetic energy of 1 g

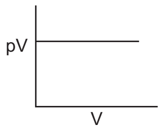
(c) The number of molecules in 1 mol

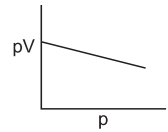
(d) The number of molecules in 1 g

53. Which of the following graphs represent Boyle's law?

(a) 

(b) 

(c) 

(d) 

54. The value of the molar gas constant is

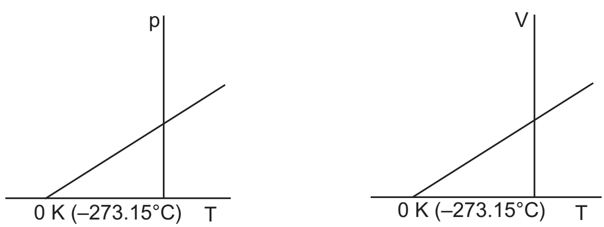
(a) 8.3145×10^3 J (kg mol)$^{-1}$ K^{-1}

(b) 1.987 cal mol K^{-1}

(c) 0.083145×10^3 dm^3 bar mol^{-1} K^{-1}

(d) 0.083145 dm^3 bar mol^{-1} K^{-1}

55. What conclusion would you draw from the following graphs?



(a) As the temperature is reduced, the volume as well as the pressure increase.

(b) As the temperature is reduced, the volume becomes zero and the pressure reaches infinity.

(c) As the temperature is reduced, the volume as well as the pressure decrease.

(d) A point is reached where, theoretically, the volume as well as the pressure become zero.

56. Which of the following statements are correct on the basis of Charles's law?

(a) The volume of an ideal gas can never be zero.

(b) The pressure of an ideal gas can be zero.

(c) At zero pressure, all molecular motion ceases in a gas, and it does not exert any pressure on the walls of the container.

(d) It is not possible to attain absolute zero.

57. Which of the following expressions is correct on the basis of the ideal gas equation?

(a) $pV = \dfrac{N}{N_A} RT$ (b) $pV = Nk_BT$ (c) $pV = \dfrac{\rho}{m} RT$ (d) $pV = \dfrac{Mk_BT}{m}$

58. Which of the following statements are correct?

(a) Helium diffuses at a rate 8.65 times as much as CO does.
(b) Helium escapes at a rate 2.65 times as fast as CO does.
(c) Helium escapes at a rate 4 times as fast as CO_2 does.
(d) Helium escapes at a rate 4 times as fast as SO_2 does.

59. According to the kinetic theory of gases,

(a) the pressure exerted by a gas is proportional to the mean square speed of the molecules
(b) the pressure exerted by a gas is proportional to the root mean square speed of the molecules
(c) the root mean square speed is inversely proportional to the temperature
(d) the mean translational kinetic energy of the molecule is directly proportional to the absolute temperature

60. Indicate the correct statement for equal volumes of N_2(g) and CO_2(g) at 298 K and 1 atm.

(a) The average translational KE per molecule is the same for N_2 and CO_2.
(b) The rms speed remains constant for both N_2 and CO_2.
(c) The density of N_2 is less than that of CO_2.
(d) The total translational KE of both N_2 and CO_2 is the same.

61. A gas can be easily liquefied

(a) when its inversion temperature equals the Boyle temperature
(b) under reversible adiabatic expansion
(c) under pressure when it is cooled to below the critical temperature
(d) at low pressure and above the critical temperature

62. Which of the following is correct for critical temperature?

(a) It is the highest temperature at which liquid and vapour can coexist.
(b) Beyond this temperature, there is no distinction between the two phases and a gas cannot be liquefied by compression.
(c) At this temperature, the surface tension of the system is zero.
(d) At this temperature, the gas and the liquid phases have different critical densities.

Answers

1. b	**2.** d	**3.** a	**4.** d	**5.** d
6. b	**7.** c	**8.** d	**9.** c	**10.** a
11. a	**12.** a	**13.** b	**14.** b	**15.** d
16. d	**17.** c	**18.** c	**19.** a	**20.** a
21. c	**22.** b	**23.** b	**24.** a	**25.** d
26. a	**27.** d	**28.** b	**29.** d	**30.** c
31. c	**32.** b	**33.** b	**34.** b	**35.** a
36. c	**37.** c	**38.** b	**39.** d	**40.** d
41. b	**42.** d	**43.** c	**44.** a	**45.** a
46. d	**47.** b	**48.** c	**49.** b	**50.** a
51. a	**52.** a, c	**53.** b, c	**54.** a, d	**55.** c, d
56. a, c, d	**57.** a, b	**58.** b, d	**59.** b, c	**60.** a, c, d
61. b, c	**62.** a, b, c			

Hints to More Difficult Problems

3. $pV = nRT.$ (i)

$N = nN_A.$ (ii)

In Equations (i) and (ii),

$$pV = \frac{N}{N_A} RT = N \frac{R}{N_A} T$$

$pV = Nk_BT \Rightarrow N = \frac{pV}{k_BT}\cdot$

where N = number of molecules.

4. $pV = nRT$ or $p = \left(\frac{nR}{V}\right)T.$

For a p–T graph, the slope $= \frac{nR}{V}\cdot$ (The equation is in the form $y = mx$.)

Thus, the slope $\propto \frac{1}{V}\cdot$

6. Density $= \frac{pM}{RT}\cdot$

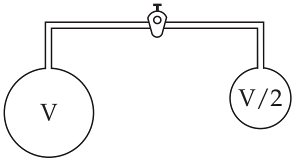
The density of a given mass of gas $\propto p \propto \frac{1}{T}\cdot$

9. 22.4 L of N_2 at stp $\equiv$ 28 g of N_2

1 L of N_2 at stp $\equiv$ 1.25 g of N_2 and 22.4 L of O_2 at stp = 32 g of O_2.

7/8 litre of O_2 at stp $\equiv$ 1.25 g of O_2.

$\therefore\ M_{N_2} = M_{O_2}.$

11. 

Let the total number of molecules of the gas be n, of which n_1 are in the larger sphere and n_2 in the smaller sphere after the stopcock is opened

$$n = n_1 + n_2 \text{ and } pV = nRT$$

$$\frac{pV}{RT_1} = \frac{p'V}{RT_1} + \frac{p'V}{2T_2R}$$

$$p' = \frac{2pT_2}{2T_2 + T_1}.$$

13. Percentage of O_2 by volume $= \dfrac{V_{O_2}}{V_{O_2} + V_{N_2}} = \dfrac{22.4\left(\frac{23}{32}\right)}{22.4\left(\frac{23}{32}\right) + 22.4\left(\frac{27}{28}\right)} = 20.7.$

(The molecular weights of O_2 and N_2 are 32 and 28 respectively.)

15. $V_{N_2O_4} = 100 \times \dfrac{2}{3}$ and $V_{NO_2} = 100 \times \dfrac{1}{3}$.

By the law of mixtures,

mass of N_2O_4 + mass of NO_2 = mass of mixture.

The vapour density of NO_2 is 23 and that of N_2O_4 is 4.

$$\frac{200}{3} \times 46 + \frac{100}{3} \times 23 = 100 \times d_{mix},$$

where d_{mix} is the vapour density of the mixture.

$\therefore$ vapour density $d = 38.3$.

16. Using $n_1T_1 = n_2T_2$, $T_2 = \dfrac{n_1}{n_2} T_1 = \dfrac{n}{(1 - 3/8)n} \times 300 = \dfrac{n}{(5/8)n} \times 300 = 480$ K.

$\therefore$ $T_2 = 207°C$.

17. Volume occupied $= \dfrac{0.0006 \text{ cm}^{-3} \times 10^3 \text{cm}^3}{1.0 \text{ g cm}^{-3}} \times 1$

$= 0.6 \text{ cm}^3$.

18. 1 L $\equiv$ 2.68 g

22.4 L $\equiv 2.68 \times 22.4 = 60$.

The molecular weight corresponds to that of COS.

22. Volume of O_2 = 100 mL and $p_{O_2} = 760 - 355 = 405$ mm.

Since the temperature is constant, using Boyle's law we get

$100\text{ mL} \times 405\text{ mm} \equiv 50\text{ mL} \times p'_{O_2}$.

$\therefore\ p'_{O_2} = 810\ \text{ mm}$

24. Volume of O_2 diffused $= \dfrac{22400 \times 0.48}{32} = 336$ mL.

Let the volume of CO_2 diffused be x mL.

Rate of diffusion of $O_2 = \dfrac{336}{1200}\text{ mL s}^{-1}$.

Rate of diffusion of $CO_2 = \dfrac{x}{1200}\text{ mL s}^{-1}$.

$$\frac{r_{O_2}}{r_{CO_2}} = \frac{V_{O_2}/t}{V_{CO_2}/t} = \sqrt{\frac{M_{CO_2}}{M_{O_2}}}$$

or $$\frac{\frac{336}{1200}}{\frac{x}{1200}} = \sqrt{\frac{44}{32}}.$$

$\therefore\ x = 286.5$ mL

28. $(U_{rms})_1 = \sqrt{\dfrac{3RT_1}{M_1}}$ for N_2 molecule, mol. wt. $M_1 = 28$.

$(U_{rms})_2 = \sqrt{\dfrac{3RT_2}{M_2}}$ for N atom, $M_2 = 14$.

$$\frac{(U_{rms})_1}{(U_{rms})_2} = \frac{\sqrt{\frac{3RT_1}{M_1}}}{\sqrt{\frac{3RT_2}{M_2}}} = \sqrt{\frac{3RT_1}{M_1} \times \frac{M_2}{3RT_2}} = \sqrt{\frac{T_2 \times 14}{28 \times 2T_2}} = \sqrt{\frac{1}{4}} = \frac{1}{2}.$$

$(U_{rms})_2 = 2(U_{rms})$.

31. Let the original volume of the bubble $= V$ and the final volume $= 8$ V.

Let p be the atmospheric pressure and p_1 the pressure at the bottom of the lake.

Using Boyle's law, $p \times 8V = p_1 \times V \Rightarrow 8p = p_1$.

p_1 = atmospheric pressure + pressure due to water in lake.

$\therefore$ pressure of water in lake $= 7p$.

Since p = pressure exerted by 10 m of water, the depth of the lake = 70 m.

33. $U_{rms} = \sqrt{\dfrac{3RT}{M}}$.

According to the question, $\left(\sqrt{\dfrac{3RT_1}{M_1}}\right) = \left(\sqrt{\dfrac{3RT_2}{M_2}}\right)_{O_2}$.

$\sqrt{\dfrac{T_1}{2}} = \sqrt{\dfrac{1600}{32}}$ or $\dfrac{T_1}{2} = \dfrac{1600}{32}$.

$\therefore \quad T_1 = 100$ K.

35. The van der Waals equation for n moles of a real gas is given by

$$\left(p + \frac{n^2 a}{V^2}\right)(V - nb) = nRT \text{ or } \left(p + \frac{a}{V_m^2}\right)(V_m - b) = RT,$$

where V_m = molar volume = V/n.

At low pressure, V_m is high and so b can be neglected.

The $\left(p + \dfrac{a}{V_n^2}\right) V_m = RT$ or $pV_m = \dfrac{a}{V_m} = RT$

$\Rightarrow pV_m = RT - \dfrac{a}{V_m}$ $\Rightarrow \dfrac{pV_m}{RT} = Z = 1 - \dfrac{a}{RTV_m}$.

$Z = 1 - \dfrac{ab}{RT} \quad \left(\because \; V \propto \dfrac{1}{p}\right)$.

38. For n moles of a real gas, the van der Waals equation becomes

$$\left(p + \frac{a}{V_m^2}\right)(V_m - b) = RT$$

At high temperature and low pressure, V_m is large in comparison to b and $\dfrac{a}{V_m^2}$ is negligibly small in comparison to p. Hence the above equation is reduced to $pV_m = RT$.

41. The less the value of a, the weaker is the intermolecular attraction.

43. Under this condition the intermolecular forces of attraction become weak and the molecules do not come close to each other. Hence real gases are difficult to compress.

61. (b) The expression for reversible adiabatic expansion is

$$\left(\frac{T_2}{T_1}\right)^{3/2} = \frac{V_1}{V_2} \Rightarrow T^{3/2} \propto \frac{1}{V} \quad \text{or} \quad V \propto \frac{1}{T^{3/2}}$$

So, on expansion, the gas cools.

(c) Greater intermolecular force of attraction

❑

5

The Mole Concept

• *Type 1* •

Choose the correct option. Only one option is correct.

1. Common salt obtained from sea-water contains 96% NaCl by mass. The approximate number of molecules present in 10.0 g of the salt is

(a) 10^{21} (b) 10^{22}

(c) 10^{23} (d) 10^{24}

2. When burnt in air, a 12.0-g mixture of carbon and sulphur yields a mixture of CO_2 and SO_2, in which the number of moles of SO_2 is half that of CO_2. The mass of the carbon the mixture contains is

(a) 4.08 g (b) 5.14 g

(c) 8.74 g (d) 1.54 g

3. In an experiment, it is found that 2.0769 g of pure X produces 3.6769 g of pure X_2O_5. The number of moles of X is

(a) 0.04 (b) 0.06

(c) 0.40 (d) 0.02

4. How many moles of $MgIn_2S_4$ can be made from 1.00 g of magnesium (of atomic mass = 24.0), 1.00 g of indium (of atomic mass = 114.8) and 1.00 g of sulphur (of atomic mass = 32.0)?

(a) 6.74×10^{-4} (b) 3.1×10^{-2}

(c) 4.17×10^{-2} (d) 8.7×10^{-3}

5. The density of water at 4°C is 1.0×10^{3} kg m^{-3}. The volume occupied by one molecule of water is approximately

(a) 3.0×10^{-23} mL (b) 6.0×10^{-22} mL

(c) 3.0×10^{-21} mL (d) 9.0×10^{-23} mL

6. When 0.5 mol of $BaCl_2$ is added to 0.2 mol of Na_3PO_4, the number of moles of $Ba_3(PO_4)_2$ formed is

(a) 0.10 (b) 0.20
(c) 0.40 (d) 0.15

7. A gaseous mixture contains $CO_2(g)$ and $N_2O(g)$ in a $2:5$ ratio by mass. The ratio of the number of molecules of $CO_2(g)$ and $N_2O(g)$ is

(a) $5:2$ (b) $2:5$
(c) $1:2$ (d) $5:4$

8. X and Y are two elements which form X_2Y_3 and X_3Y_4. If 0.20 mol of X_2Y_3 weighs 32.0 g and 0.4 mol of X_3Y_4 weighs 92.8 g, the atomic weights of X and Y are respectively

(a) 16.0 and 56.0 (b) 8.0 and 28.0
(c) 56.0 and 16.0 (d) 28.0 and 8.0

9. When 1 L of CO_2 is heated with graphite, the volume of the gases collected is 1.5 L. Calculate the number of moles of CO produced at stp.

(a) $\frac{1}{11.2}$ (b) $\frac{28}{22.4}$
(c) $\frac{1}{22.4}$ (d) $\frac{14}{22.4}$

10. Sulphur trioxide is prepared by the following two reactions.

$$S_8(s) + 8O_2(g) \longrightarrow 8SO_2(g)$$
$$2SO_2(g) + O_2(g) \longrightarrow 2SO_3(g)$$

How many grams of SO_3 are produced from 1 mol of S_8?

(a) 1280.0 (b) 640.0
(c) 960.0 (d) 320.0

11. A quantity of aluminium has a mass of 54.0 g. What is the mass of the same number of magnesium atoms?

(a) 12.1 g (b) 24.3 g
(c) 48.6 g (d) 97.2 g

12. If the atomic weight of carbon is taken to be 6 amu, the value of the Avogadro constant will be

(a) $12.04 \times 10^{23}\ mol^{-1}$ (b) $3.01 \times 10^{23}\ mol^{-1}$
(c) $1.5 \times 10^{23}\ mol^{-1}$ (d) $6.02 \times 10^{23}\ mol^{-1}$

13. The charge on 1 gram ion of Al^{3+} is

(a) $\frac{1}{27} N_A e$ coulomb (b) $\frac{1}{3} \times N_A e$ coulomb
(c) $\frac{1}{9} N_A e$ coulomb (d) $3 \times N_A e$ coulomb

14. How many moles of HCl will be present in 100 mL of a solution of specific gravity 1.08, containing 20% HCl by mass?

(a) 0.50 (b) 0.60

(c) 0.80 (d) 0.12

15. The density in grams per litre of a mixture containing an equal number of moles of methane and ethane at stp is

(a) 1.03 (b) 1.10

(c) 0.94 (d) 1.20

16. Equal weights of ethane and hydrogen are mixed in an empty vessel at 25°C. The fraction of the total pressure exerted by hydrogen is

(a) $\frac{1}{2}$ (b) $\frac{1}{1}$

(c) $\frac{1}{16}$ (d) $\frac{15}{16}$

17. n mol of N_2 and 0.05 mol of Ar are enclosed in a vessel of capacity 2 L at 1 atm and 27°C. Find n. ($R = 0.082$ L atm mol K^{-1}.)

(a) 0.30 (b) 0.10 (c) 0.03 (d) 0.06

18. 112.0 mL of NO_2 at stp was liquefied, the density of the liquid being 1.15 g mL^{-1}. Calculate the volume of and the number of molecules in the liquid NO_2.

(a) 0.10 mL and 3.01×10^{22} (b) 0.20 mL and 3.01×10^{21}

(c) 0.20 mL and 6.02×10^{23} (d) 0.40 mL and 6.02×10^{21}

19. The mass of 1×10^{22} molecules of $CuSO_4.5H_2O$ is

(a) 4.144 g (b) 8.288 g

(c) 2.648 g (d) 5.295 g

20. A semiconductor $YBa_2Cu_3O_7$ is prepared by a reaction involving Y_2O_3, BaO_2 and CuO. The ratio of their moles should be

(a) 1 : 2 : 4 (b) 1 : 2 : 3

(c) 3 : 2 : 1 (d) 1 : 1.5 : 2.5

21. 254 g of iodine and 142 g of chlorine are made to react completely to give a mixture of ICl and ICl_3. How many moles of each are formed?

(a) 0.1 mol of ICl and 0.1 mol of ICl_3

(b) 1.0 mol of ICl and 1.0 mol of ICl_3

(c) 0.5 mol of ICl and 0.1 mol of ICl_3

(d) 0.5 mol of ICl and 1.0 mol of ICl_3

22. The number of molecules in 100 mL of 0.02-N H_2SO_4 is

(a) 6.02×10^{20} (b) 6.02×10^{18}

(c) 6.02×10^{21} (d) 6.02×10^{22}

23. For the reaction $2P + Q \rightarrow R$, 8 mol of P and 5 mol of Q will produce

(a) 8 mol of R (b) 5 mol of R
(c) 4 mol of R (d) 13 mol of R

24. Which of the following contains the greatest number of atoms?

(a) 1.0 g of butane (C_4H_{10}) (b) 1.0 g of nitrogen (N_2)
(c) 1.0 g of silver (Ag) (d) 1.0 g of water (H_2O)

25. Under the same conditions, two gases have the same number of molecules. They must

(a) be noble gases
(b) have equal volumes
(c) have a volume of 22.4 dm^3 each
(d) have an equal number of atoms

26. The molar mass of N_2O as well as CO_2 is 44 g mol^{-1}. At 25°C and 1 atm, N_2O contains n molecules of gas. The number of molecules in 2.0 L of CO_2 under the same conditions is

(a) $\frac{n}{4}$ (b) $\frac{n}{8}$
(c) $4n$ (d) n

27. Two flasks P and Q of the same capacity contain helium and hydrogen respectively at 27°C and 1 atmospheric pressure. Flask P contains

(a) the same number of atoms as Q does
(b) half the number of atoms as Q does
(c) twice the number of atoms as Q does
(d) gas of the same weight as Q does.

28. Samples of 1.0 g of Al are treated separately with an excess of sulphuric acid and an excess of sodium hydroxide. The ratio of the numbers of moles of the hydrogen gas evolved is

(a) 1 : 1 (b) 3 : 2
(c) 2 : 1 (d) 9 : 4

29. The number of molecules of water in 333 g of $Al_2(SO_4)_3.18H_2O$ is

(a) $18.0 \times 6.02 \times 10^{23}$ (b) $9.0 \times 6.02 \times 10^{23}$
(c) 18.0 (d) 36.0

30. The vapour density of a mixture containing NO_2 and N_2O_4 is 38.3 at 300 K. The number of moles of NO_2 in 100 g of the mixture is approximately

(a) 0.44 (b) 4.4
(c) 33.4 (d) 3.34

31. The atomic weights of two elements A and B are 40 and 80 respectively. If x g of A contains y atoms, how many atoms are present in $2x$ g of B?

(a) $\frac{y}{2}$ (b) $\frac{y}{4}$ (c) y (d) $2y$

32. The Loschmidt number is the number of

(a) molecules present in 1 mL of a gas at stp
(b) molecules in 1 gram mole of a gas at stp
(c) atoms present in 1 mL of a gas at stp
(d) atoms present in 1 gram mole of a gas at stp

33. 5.85 g of NaCl is dissolved in 1 L of pure water. The number of ions in 1 mL of this solution is

(a) 6.02×10^{19} (b) 1.2×10^{22}
(c) 1.2×10^{20} (d) 6.02×10^{20}

34. The measured mass of a ${}^2_1H$ atom is 2.014 amu, which is 0.0024 amu less than the combined mass of a ${}^1_1H$ atom and a neutron. The energy corresponding to the missing mass is

(a) 1.2 MeV (b) 2.2 MeV
(c) 0.22 MeV (d) 2.8 MeV

35. The rest mass of 1 mol of neutrons ($m_n = 1.675 \times 10^{-27}$ kg) is

(a) 1.800×10^{-3} kg (b) 1.008×10^{-4} kg
(c) 1.080×10^{-3} kg (d) 1.008×10^{-3} kg

36. From 392 mg of H_2SO_4, 1.204×10^{21} molecules are removed. How many moles of H_2SO_4 are left?

(a) 2.0×10^{-3} (b) 1.2×10^{-3} (c) 4.0×10^{-3} (d) 1.5×10^{-3}

37. Which of the following is arranged in order of increasing weight?

(a) 0.625 g of Fe < 0.0105 equivalent of $H_2C_2O_4.2H_2O < 6.02 \times 10^{21}$ atoms of Zn < 0.006 g atom of Ag
(b) 0.625 g of Fe < 6.02×10^{21} atoms of Zn < 0.006 g atom of Ag < 0.0105 equivalent of $H_2C_2O_4.2H_2O$
(c) 0.0105 equivalent of $H_2C_2O_4.2H_2O$ < 0.006 g atom of Ag < 6.02×10^{21} atom of Zn < 0.625 g of Fe
(d) 0.0105 equivalent of $H_2C_2O_4.2H_2O$ < 0.625 g of Fe < 0.006 g atom of Ag < 6.02×10^{21} atoms

38. A mixture of $C_2H_4(g)$ and $C_3H_8(g)$ was kept in a 0.820-L vessel at 1 atm and 300 K. The weight of the gas mixture in the vessel is 0.613 g. Calculate the ratio of the numbers of moles of $C_3H_8(g)$ and $C_2H_4(g)$.

(a) 1.54 (b) 1.68 (c) 1.44 (d) 1.60

• *Type 2* •

Choose the correct options. More than one option is correct.

39. Which of the following expressions is correct (n = no. of moles of the gas, N_A = Avogadro constant, m = mass of 1 molecule of the gas, N = no. of molecules of the gas)?

(a) $n = mN_A$ (b) $m = nN_A$

(c) $N = nN_A$ (d) $m = mn/N_A$

40. In which of the following pairs do 1 g of each have an equal number of molecules?

(a) N_2O and CO (b) N_2 and C_3O_2

(c) N_2 and CO (d) N_2O and CO_2

41. Among the following, which solutions contain equal numbers of millimoles?

(a) 100 mL of 0.05 M H_2SO_4 (b) 200 mL of 0.05 M NaOH

(c) 100 mL of 0.010 M $Na_2C_2O_4$ (d) 200 mL of 0.025 M KOH

42. 1 mol of ${}^{14}_{7}N^{-3}$ ions contains

(a) $7N_A$ electrons (b) $7N_A$ protons

(c) $7N_A$ neutrons (d) $14N_A$ protons

43. 11.2 L of a gas at stp weighs 14.0 g. The gas could be

(a) N_2O (b) NO_2

(c) N_2 (d) CO

Answers

1. c	**2.** b	**3.** a	**4.** d	**5.** a
6. a	**7.** b	**8.** c	**9.** c	**10.** b
11. c	**12.** b	**13.** d	**14.** b	**15.** a
16. d	**17.** c	**18.** b	**19.** a	**20.** b
21. b	**22.** a	**23.** c	**24.** a	**25.** b
26. d	**27.** b	**28.** a	**29.** b	**30.** a
31. c	**32.** a	**33.** c	**34.** b	**35.** d
36. a	**37.** b	**38.** a	**39.** b, c	**40.** c, d
41. a, d	**42.** b, c	**43.** c, d		

Hints to More Difficult Problems

4. The number of moles of Mg, In, and S are respectively $\frac{1}{24}$, $\frac{1}{114.8}$ and $\frac{1}{32}$ $= 0.0417$, 0.0087 and 0.031. The number of moles of the limiting reagent is $0.0087 = 8.7 \times 10^{-3}$.

5. $N = nN_A$.

$1 = n \times 6.02 \times 10^{23}$ or $n = 1.66 \times 10^{-24}$ g

or $\text{wt} = n \cdot (\text{Mol. wt.}) = 1.66 \times 10^{-24} \text{ mol} \times 18.0 \text{ g mol}^{-1}$

$= 3.0 \times 10^{-23}$ g.

8. Molecular weight of $X_2Y_3 = \frac{32.0 \text{ g}}{0.2 \text{ mol}} = 160 \text{ g mol}^{-1}$.

Molecular weight of $X_3Y_4 = \frac{92.8 \text{ g}}{0.4 \text{ mol}} = 232 \text{ g mol}^{-1}$.

Let atomic weight of X be a and that of Y be b. Then $2a + 3b = 160$ and $3a + 4b = 232$.

Solving, we get

$a = 56$ and $b = 16$.

9. $$\underset{1-x}{CO_2(g)} + C(s) \longrightarrow \underset{2x}{2CO(g)}$$

According to the question,

$$1 - x + 2x = 1.5 \Rightarrow x = 0.5 \text{ L} \Rightarrow 2x = 1.0 \text{ L} = 1/22.4 \text{ mol}.$$

13. 1 gram ion means 1 mole.

$\therefore$ charge $= 3 \times N_A \times e$ coulomb.

14. Wt. of HCl solution $= 100 \times 1.08 = 108.0$ g

Wt. of HCl $= \frac{20}{100} \times 108.0 = 21.6$ g

$\therefore$ no. of moles of HCl $= \frac{21.6}{36.5} \approx 0.6$.

16. Let the total weight be x.

The fraction of the total pressure $= \dfrac{\frac{1}{2x}}{\frac{1}{2}x + \frac{1}{30}x} = \frac{15}{16}$.

18. $W_{NO_2} = \dfrac{112.0 \text{ mL} \times 46.0 \text{ g mol}^{-1}}{22400 \text{ mL mol}^{-1}} = 0.23$ g.

$V_{NO_2, l} = \dfrac{0.23 \text{ g}}{1.15 \text{ g mL}^{-1}} = 0.20$ mL.

$N = mN_A = \frac{0.23}{46} \times 6.02 \times 10^{23} = 3.01 \times 10^{21}$.

22. 100.0 mL of 0.02 $H_2SO_4 = 100 \times 0.02$ m eq. = 2 m eq. = 1 m mol
$= 1 \times 10^{-3} \times 6.02 \times 10^{23} = 6.02 \times 10^{20}$ molecules.

31. No. of moles of A $= \dfrac{x}{40}\cdot$

Number of atoms of A $= \dfrac{x}{40} \times N_A = y$ (say) or $x = \dfrac{40y}{N_A}\cdot$

No. of moles of B $= \dfrac{2x}{80}\cdot$

No. of atoms of B $= \dfrac{2x}{80} N_A = \dfrac{2}{80} \times \dfrac{40y}{N_A} N_A = y$

33. Molarity of NaCl $= \dfrac{5.85}{58.5} = 0.1$ M.

1 mL of NaCl $= 10^{-4}$ mol.
1 mole of NaCl $= 6.02 \times 10^{23}$ molecules of NaCl.
But NaCl molecules are dissociated into two ions (Na^+ and Cl^-).
1 mol of NaCl $= 6.02 \times 10^{23} \times 2$ ions.
1×10^{-4} mole of NaCl $= 1 \times 10^{-4} \times 6.02 \times 10^{23} \times 2$ ions
$= 1.2 \times 10^{20}$ ions.

34. Energy $= 0.0024 \times 931.5$ MeV $= 2.2$ MeV.

35. Mass of 1 mole $= 1.675 \times 10^{-27} \times 6.02 \times 10^{23}$ kg
$= 1.008 \times 10^{-3}$ kg

36. No. of moles of $H_2SO_4 = \dfrac{0.392}{98} = 0.004.$

$$N = nN_A \Rightarrow n = \frac{N}{N_A} = \frac{1.204 \times 10^{21} \text{ molecules}}{6.02 \times 10^{23} \text{ molecules}} = 0.002.$$

No. of moles of H_2SO_4 left $= 0.004 - 0.002 = 0.002 = 2.0 \times 10^{-3}$.

38. Let the number of moles of C_2H_4 and C_3H_8 be x and y respectively. Using the formula

$pV = nRT$,

1 atm $\times$ 0.820 L $= (x + y)$ mol $\times$ 0.082 L-atm K^{-1} mol^{-1} $\times$ 300 K

or $x + y = \dfrac{1}{30}\cdot$ (i)

Again, $28x + 44y = 0.613.$ (ii)

Solving, we get $\dfrac{y}{x} = 1.54.$

43. Calculate mol. wt. $= \dfrac{W}{V} \times 22.4 = \dfrac{14.0}{11.2} \times 22.4 = 28$ g mol^{-1}.

This molecular weight corresponds to N_2(g) and CO(g).

❑

6

Calculations Based on Chemical Equations and Eudiometry

• *Type 1* •

Choose the correct option. Only one option is correct.

1. 1.00×10^{-3} mol of Ag^+ and 1.00×10^{-3} mol of CrO_4^{2-} react together to form solid Ag_2CrO_4. Calculate the amount of Ag_2CrO_4 formed ($Ag_2CrO_4 = 331.73$ g mol^{-1}).

(a) 0.268 g (b) 0.166 g
(c) 0.212 g (d) 1.66 g

2. 1.00 g of $Cr_2O_7^{2-}$ is oxidized in an acidic solution by an excess of SO_2 to form HSO_4^- and Cr^{3+}. What is the minimum number of moles of H^+ that must be produced for this reaction to occur ($Cr_2O^{2-} = 216$)?

(a) 0.0231 (b) 0.0282
(c) 0.0322 (d) 0.0268

3. In an acidic solution, I^- changes to I_2. How many grams of I_2 are produced if, in the same process, 1.5×10^{22} electrons are used up to reduce H_3AsO_4 to H_3AsO_3 ($I = 127$)?

(a) 1.6 g (b) 6.4 g
(c) 4.8 g (d) 3.2 g

4. What would be the weight of the slaked lime required to decompose 8.0 g of ammonium chloride?

(a) 5.53 g (b) 2.12 g (c) 15.52 g (d) 7.62 g

5. The number of moles of $Cr_2O_7^{2-}$ needed to oxidize 0.136 equivalent of $N_2H_5^+$ through the reaction

$$N_2H_5^+ + Cr_2O_7^{2-} \longrightarrow N_2 + Cr^{3+} + H_2O$$

is

(a) 0.236 (b) 0.087 (c) 0.136 (d) 0.488

6. On being strongly heated, 2.76 g of Ag_2CO_3 yields a residue weighing

(a) 3.48 g (b) 1.44 g

(c) 2.16 g (d) 4.16 g

7. An impure sample of silver weighing 2.50 g is dissolved in HNO_3 and the silver is precipitated to yield 2.50 g of AgCl. What is the percentage by weight of silver in the original sample (Ag = 108, Cl = 35.5)?

(a) 75.26 (b) 100.00

(c) 50.26 (d) 88.45

8. Sulphuric acid is produced when sulphur dioxide reacts with oxygen and water in the presence of a catalyst.

$$2SO_2(g) + O_2(g) + 2H_2O(l) \longrightarrow 2H_2SO_4(aq)$$

If 5.6 mol of SO_2 reacts with 4.8 mol of O_2 and a large excess of water, what is the maximum number of moles of H_2SO_4 that can be obtained?

(a) 5.6 (b) 11.2

(c) 2.4 (d) 1.4

9. 8.7 g of pure MnO_2 is heated with an excess of HCl and the gas evolved is passed into a solution of KI. Calculate the weight of the iodine liberated (Mn = 55, Cl = 35.5, I = 127).

(a) 7.7 g (b) 15.4 g

(c) 12.7 g (d) 25.4 g

10. Equal weights (1.00 g) of iron and sulphur are heated together and react to form FeS. What fraction of the original weight is left unreacted (Fe = 55.85 g mol^{-1}, S = 32.10 g mol^{-1})?

(a) 0.225 (b) 0.425

(c) 0.875 (d) 0.575

11. Pure FeS_2 is burnt with 60% excess air. Calculate the percentage of N_2 by volume after the reaction.

(a) 81.94 (b) 9.89

(c) 8.17 (d) 89.26

12. In a textile mill, a double-effect evaporator system concentrates weak liquor containing 4% (by weight) caustic soda to produce a lye containing 25% solids (by weight). Calculate the weight of the water evaporated per 100-kg feed in the evaporator.

(a) 125.0 g (b) 50.0 g

(c) 84.0 g (d) 16.0 g

13. An ammonium sulphate solution of concentration 0.05 kg mol^{-1} reacts with calcium hydroxide. How many litres of a solution (specific gravity 0.92) containing 20.5% by weight of ammonia can be prepared using this reaction?

(a) 12.0 L (b) 9.0 L (c) 18.0 L (d) 4.5 L

14. Calculate the number of millilitres (at stp) of hydrogen sulphide needed to precipitate cupric sulphide completely from 100 mL of a solution containing 0.75 g of $CuCl_2$ in a 1-L solution.

(a) 21.4 (b) 14.2
(c) 41.2 (d) 12.4

15. Aluminium metal is prepared by the electrolysis of a solution of Al_2O_3 in molten cryolite (Na_3AlF_6). Assuming that all of the aluminium comes from Al_2O_3, how much of the latter would be needed for each tonne of aluminium produced (Al = 27, O = 16)?

(a) 1.88 tonne (b) 2.88 tonne
(c) 1.68 tonne (d) 1.44 tonne

16. $2PbS + 3O_2 \longrightarrow 2PbO + 2SO_2$

$3SO_2 + 2HNO_3 + 2H_2O \longrightarrow 3H_2SO_4 + 2NO$

According to the above sequence of reactions, how much H_2SO_4 will 1146 g of PbS produce?

(a) 245.2 g (b) 490.4 g
(c) 484.6 g (d) 409.5 g

17. An alloy of aluminium and copper is treated with aqueous HCl. The aluminium dissolves according to the reaction

$$Al + 3H^+ \longrightarrow Al^{3+} + \frac{3}{2}H_2$$

but the copper remains as pure metal. A 0.50-g sample of the alloy gives 560 mL of H_2 at stp. The percentage of aluminium by weight in the alloy is (Al = 27)

(a) 90 (b) 85
(c) 78 (d) 96

18. An ore contains 2.0% of the mineral argentite (Ag_2S) by weight. How much of this ore will have to be processed to obtain 1.00 g of pure solid silver (Ag = 108, S = 32)?

(a) 45.7 g (b) 67.4 g
(c) 57.4 g (d) 87.6 g

19. An organic compound contains 20 atoms of carbon per molecule, the percentage of carbon by weight being 70. The gram molecular mass of the organic compound is approximately

(a) 465.0 (b) 365.0
(c) 415.0 (d) 667.0

20. What is the maximum amount of nitrogen dioxide that can be produced by mixing 4.2 g of NO(g) and 3.2 g of O_2(g)?

(a) 4.60 g (b) 2.30 g
(c) 3.22 g (d) 6.44 g

21. Calculate the volume required of a 20.0% HCl solution of density $1.20\ g\ mL^{-1}$ to prepare 363.0 g of $AsCl_3$ according to the equations (As = 75, Cl = 35.5)

$$2KMnO_4 + 16HCl \rightarrow 2KCl + 2MnCl_2 + 5Cl_2 + 8H_2O$$
$$\text{and } 2As + 3Cl_2 \rightarrow 2AsCl_3$$

is

(a) 2.56 L (b) 0.73 L
(c) 1.46 L (d) 2.92 L

22. 1 L of an acidified solution containing 31.6 g of $KMnO_4$ is decolourized by passing SO_2 through it. How much iron pyrites (FeS_2) has to be roasted to produce the necessary amount of SO_2 (K = 39, Mn = 55, S = 32, Fe = 56)?

(a) 30.0 g (b) 7.5 g
(c) 15.0 g (d) 45.0 g

23. 2.0 g of dolomite was heated to a constant weight of 1.0 g. Calculate the total volume of the CO_2 produced at stp (Ca = 40, Mg = 24, C = 12, O = 16) by this reaction.

(a) 482.4 mL (b) 502.6 mL
(c) 492.8 mL (d) 428.6 mL

24. 1 g of a mixture of $NaHCO_3$ and Na_2CO_3 is heated to 150°C. The volume of the CO_2 produced at stp is 112.0 mL. Calculate the percentage of Na_2CO_3 in the mixture (Na = 23, C = 12, O = 16).

(a) 20 (b) 46
(c) 84 (d) 16

25. 2 g of impure $CaCO_3$ reacts with HCl to produce 410 mL of CO_2 at 1 atmospheric pressure and 27°C. Calculate the percentage purity of the $CaCO_3$ used.

(a) 83.5 (b) 97.5
(c) 87.5 (d) 73.5

26. 60 g of NaOH is converted into NaCl and $NaClO_3$ by the action of Cl_2. The Cl_2 is produced by the reaction between MnO_2 and concentrated HCl. The amount of MnO_2 required for the process (Mn = 55, Na = 23) is

(a) 70.95 g (b) 25.65 g
(c) 65.25 g (d) 75.45 g

27. The atomic weight of Cu is 63.546. There are only two naturally occurring isotopes of copper, ^{63}Cu and ^{65}Cu. The natural abundance of the ^{63}Cu isotope is approximately

(a) 20% (b) 70%
(c) 30% (d) 80%

28. 15.0 mL of N_2O is passed over heated copper. The volume of the $N_2(g)$ obtained is

(a) 15.0 mL (b) 7.5 mL
(c) 30.0 mL (d) 45.0 mL

29. A mixture of CH_4 and C_2H_4 was completely burnt in an excess of oxygen, yielding equal volumes of CO_2 and steam. Calculate the percentages of the compounds in the original mixture.

(a) 25% CH_4 and 75% C_2H_4 (b) 30% CH_4 and 70% C_2H_4
(c) 75% CH_4 and 25% C_2H_4 (d) 50% CH_4 and 50% C_2H_4

30. 1 mol of a gaseous aliphatic compound $C_nH_{3n}O_m$ is completely burnt in an excess of oxygen. The contraction in volume is

(a) $\left(1+\frac{1}{2}n-\frac{3}{4}m\right)$ (b) $\left(1+\frac{3}{4}n-\frac{1}{4}m\right)$
(c) $\left(1-\frac{1}{2}n-\frac{3}{4}m\right)$ (d) $\left(1+\frac{3}{4}n-\frac{1}{2}m\right)$

31. 10.0 mL of a gaseous organic compound containing C, H and O was mixed with 100.0 mL of oxygen gas, causing an explosion. The volume of the gas after the explosion was 90.0 mL. On treatment with a KOH solution, a further contraction in volume was observed. Calculate the number of moles of the carbon dioxide produced.

(a) 1.0 (b) 3.0
(c) 2.0 (d) 4.0

32. 40.0 mL of a gaseous mixture of CO and C_2H_2 is mixed with 100.0 mL of O_2 and burnt. The volume of the gas after the combustion is 10.5 mL. Calculate the composition of the original mixture.

(a) 25 mL of CO and 15 mL of C_2H_2
(b) 15 mL of CO and 25 mL of C_2H_2
(c) 10 mL of CO and 30 mL of C_2H_2
(d) 20 mL of CO and 20 mL of C_2H_2

33. What is the volume of air required for the complete combustion of 20.0 L of methane?

(a) 840 L (b) 240 L
(c) 240 L (d) 192 L

34. 200.0 mL of oxygen is added to 100.0 mL of a mixture containing CS_2 vapour and CO, and the total mixture is burnt. After combustion, the volume of the entire mixture is 245.0 mL. Calculate the volume of the oxygen that remains.

(a) 67.5 mL (b) 125.0 mL
(c) 200.0 mL (d) 100.0 mL

35. 80 mL of oxygen is added to 50 mL of a mixture of H_2, C_2H_2 and CO, after which the total mixture is burnt. The volume of the cooled mixture after combustion measures 65 mL. This is reduced to 15 mL by treatment with a KOH solution. Calculate the volume of each gas in the original mixture.

(a) 20 mL of H_2, 20 mL of C_2H_2, 10 mL of CO
(b) 10 mL of H_2, 20 mL of C_2H_2, 20 mL of CO
(c) 15 mL of H_2, 15 mL of C_2H_2, 20 mL of CO
(d) 20 mL of H_2, 25 mL of C_2H_2, 5 mL of CO

36. 30 mL of a gaseous hydrocarbon requires 90 mL of O_2 for complete combustion, 60 mL of CO_2 being formed in the process. The molecular formula of the hydrocarbon is

(a) C_2H_2 (b) C_3H_8
(c) C_4H_{10} (d) C_2H_4

37. 50 mL of a mixture of C_2H_4 and C_2H_2 was mixed with 150 mL of O_2 and burnt. The volume of the cooled mixture of gases after the combustion is 112.5 mL. The percentage of C_2H_4 in the original mixture is

(a) 75 (b) 60
(c) 50 (d) 40

38. 12 mL of the vapour of a certain organic compound containing only carbon, hydrogen and oxygen is heated. After being cooled to the original room temperature, its volume becomes 100 mL. Treatment with aqueous KOH removes CO_2, leaving 88 mL of O_2. The empirical formula of the vapour is

(a) C_3H_6O (b) CH_2O
(c) C_2H_4O (d) $C_2H_4O_2$

39. A volume V of a gaseous hydrocarbon was exploded with an excess of oxygen. The observed contraction was $2\frac{1}{2}V$, and on treatment with potash, there was a further contraction of $2V$. What is the molecular formula of the hydrocarbon?

(a) C_2H_6 (b) C_3H_6 (c) C_4H_{12} (d) C_2H_4

40. 20 mL of a gaseous hydrocarbon was exploded with 120 mL of oxygen. A contraction of 60 mL was observed, and a further contraction of 60 mL took place when an alkali was added. What is the formula of the hydrocarbon?

(a) C_3H_6 (b) C_3H_8
(c) C_2H_6 (d) C_4H_{10}

41. 2 g of a mixture of Cu_2O and CuO was quantitatively reduced to 1.7 g of metallic copper. Calculate the weight of CuO in the original sample (Cu = 63.5, O = 16)?

(a) 0.85 g (b) 0.55 g (c) 0.75 g (d) 0.95 g

42. A gaseous mixture of ethene and ethyne measuring 50 mL is mixed with 150 mL of O_2 and burnt. After combustion and cooling, the volume of the mixture of gases is 112.5 mL. Calculate the percentage by volume of ethene in the mixture.

(a) 75 (b) 60

(c) 50 (d) 80

43. 50.0 mL of a gaseous mixture of H_2 and HCl is exposed to a sodium amalgam. The volume decreases to 42.5 mL. If 100.0 mL of the same mixture is added to 50.0 mL of gaseous ammonia and then exposed to water, what will be the volume of the final mixture?

(a) 35.0 mL (b) 50.0 mL

(c) 15.0 mL (d) 70.0 mL

44. A gaseous organic compound containing C, H and N, which is completely burnt in an excess of oxyen, produces

(a) x vol. of $CO_2(s) + \frac{y}{2}$ vol. of $H_2O(g)\ \frac{z}{2}$ vol. of $NO_2(g)$

(b) x vol. of $CO_2(g) + \frac{y}{2}$ vol. of $H_2O(l)\ \frac{z}{2}$ vol. of $N_2(g)$

(c) x vol. of $CO_2 + \frac{y}{2}$ vol. of $H_2O(l)$

(d) x vol. of $CO_2(s) + \frac{y}{2}$ vol. of $H_2O(s) + z$ vol. of $N_2(g)$

45. Three volumes of a gaseous hydrocarbon containing carbon, hydrogen and sulphur is burnt in an excess of oxygen to yield three volumes of CO_2, three volumes of SO_2 and six volumes of water vapour. The formula of the compound is

(a) C_6H_6S (b) C_4H_4S (c) CH_4S (d) C_2H_6S

• Type 2 •

Choose the correct options. More than one option is correct.

46. Calculate the amount of lime (CaO) produced by heating 100 g of 90% pure limestone.

(a) 50.4 g (b) 0.98 mol

(c) 0.90 mol (d) 56.0 g

47. 2 mol of CO_2 is required to prepare

(a) 336 g of $NaHCO_3$ (b) 168 g of $NaHCO_3$

(c) 462 g of $Ca(HCO_3)_2$ (d) 162 g of $Ca(HCO_3)_2$

48. 1.5 g of oxygen is produced by heating $KClO_3$. How much KCl is produced in the reaction?

(a) 4.15×10^{-2} mol (b) 4.33 g

(c) 1.78×10^{-2} mol (d) 1.33 g

49. Which of the following gases are absorbed by an ammoniacal cuprous chloride solution?

(a) NO (b) CO

(c) O_3 (d) C_2H_2

50. 50 millilitres of CO is mixed with 20 mL of oxygen and sparked. After the reaction, the mixture is treated with an aqueous KOH solution. Choose the correct option.

(a) The volume of the CO that reacts = 40 mL.

(b) The volume of the CO_2 formed = 40 mL.

(c) The volume of the CO that remains after treatment with KOH = 10 mL.

(d) The volume of the CO that remains after treatment with KOH = 20 mL.

Answers

1. b	**2.** a	**3.** d	**4.** a	**5.** c
6. c	**7.** a	**8.** a	**9.** d	**10.** b
11. a	**12.** c	**13.** b	**14.** d	**15.** a
16. b	**17.** a	**18.** c	**19.** b	**20.** d
21. c	**22.** a	**23.** c	**24.** d	**25.** a
26. c	**27.** b	**28.** a	**29.** d	**30.** d
31. c	**32.** a	**33.** d	**34.** b	**35.** a
36. d	**37.** c	**38.** b	**39.** a	**40.** b
41. a	**42.** c	**43.** d	**44.** b	**45.** c
46. a, c	**47.** a, d	**48.** c, d	**49.** b, d	**50.** a, b, c

Hints to More Difficult Problems

1. The reaction is $2Ag^+ + CrO_4^{2-} \longrightarrow Ag_2CrO_4$. Using the limiting-reagent concept, no. of moles of $Ag_2CrO_4 = 0.5 \times 10^{-3} \times 331.73 = 0.166$ g.

2. The reaction is

$Cr_2O_7^{2-} + 3SO_2 + 5H^+ \longrightarrow 3HSO_4^- + 2Cr^{3+} + H_2O$

No. of moles of $H^+ = \dfrac{1.0}{216} \times 5 = 0.0231$ $\quad [Cr_2O_7^{2-} = 2 \times 52 + 7 \times 16 = 216]$

4. $2NH_4Cl \quad + \quad Ca(OH)_2 \longrightarrow CaCl_2 + 2NH_3 + 2H_2O$

2×53.5 g $\quad (40 + 34)$ g

Wt. of $Ca(OH)_2$ required $= \dfrac{74}{107} \times 8 = 5.53$ g.

7. Since the weights of the sample and the precipitated AgCl are equal, the required amount is given by the

weight percentate of silver in AgCl $= \dfrac{108}{108 + 35.5} \times 100 = 75.25$

9. $MnO_2 + 4HCl \longrightarrow MnCl_2 + 2H_2O + Cl_2$

$Cl_2 + 2KI \longrightarrow 2KCl + I_2$

The number of moles of MnO_2 equals that of I_2.

Thus, 87 g liberates 254 g of I_2.

Therefore 8.7 g of MnO_2 corresponds to 25.4 g of I_2.

10. Use the limiting-reagent concept.

	Fe	+	S	$\longrightarrow$	FeS
	1/55.85		1/32.1		
no. of moles $\longrightarrow$	0.017905		0.031153		0.017905

Unreacted sample = 0.031153 − 0.017905 = 0.013248

Weight of unreacted sample = 0.013248 × 32.1 g = 0.425 g

12. 100 kg of weak liquor (feed) contains 4 kg of caustic soda. Let the quantity of the lye be x kg. Then the amount of caustic soda in the lye $= 0.25\,x$. However caustic soda does not take part in the evaporation

$\therefore \quad 0.25\,x = 4 \Rightarrow x = 16$ kg

The weight of the water that evaporates = 100.0 − 16.0 = 84.0 kg

17. 1.5×22400 mL of H_2 at stp = 27 g of Al

560 mL of H_2 at stp = 0.45 g of Al

$\therefore \quad$ Percentage of Al $= \dfrac{0.45}{0.50} \times 100 = 90$

18. Ag_2S has two atoms of Ag.

Therefore, 216 g of Ag corresponds to 248 g of Ag_2S.

1 g of Ag is contained in $= \dfrac{248}{216}$ g of Ag_2S

wt. of the ore $= \dfrac{248}{216} \times \dfrac{100}{2} = 57.4$ g

19. Gram molecular mass of carbon

$$= \frac{\text{no. of atoms} \times \text{At. mass of C} \times 1\ \text{amu} \times N_A}{\text{percentage of carbon}}$$

$$= \frac{20 \times 12 \times 1.66 \times 10^{-24}\ \text{g} \times 6.02 \times 10^{23}\ \text{mol}^{-1}}{70/100}$$

$= 365.0$ g mol^{-1}

20. No. of moles of NO $= \dfrac{4.2\ \text{g}}{30} = 0.14$

No. of moles of $O_2 = \dfrac{3.2\ \text{g}}{32} = 0.10$

$2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$

Using the limiting reagent concept,

$W_{NO_2} = 0.14\ \text{mol} \times 46\ \text{g mol}^{-1}$

$= 6.44$ g

22. $4FeS_2 + 11O_2 \longrightarrow 2Fe_2O_3 + 8SO_2$

$2KMnO_4 + 5SO_2 + 2H_2O \longrightarrow H_2SO_4 + 2MnSO_4 + 2H_2SO_4$

$\dfrac{8}{5}(2KMnO_4) \equiv 8SO_2 \equiv 4FeS_2$

$\dfrac{16}{5}$ mol of $KMnO_4 \equiv 4$ mol of FeS_2

No. of moles of $KMnO_4 = \dfrac{31.6}{158} = 0.2$

0.2 mol of $KMnO_4 \equiv \dfrac{4}{16/5} \times 0.2$ mol of FeS_2

$= \dfrac{1}{4}$ mol of $FeS_2 = \dfrac{1}{4} \times 120$ g

$= 30.0$ g

23.

$CaCO_3 \longrightarrow$	CaO + CO_2	$MgCO_3 \longrightarrow$	MgO + CO_2
100.0 g	56.0 g	84.0 g	40.0 g
x g	$\dfrac{56}{100}x$ g	$(2.0 - x)$ g	$\dfrac{40.0}{84.0}(2.0 - x)$ g

According to the question,

$\dfrac{56.0}{100.0}x + \dfrac{40.0}{84.0}(2.0 - x) = 1 \quad \therefore \quad x = 1.0\ \text{g} \quad 2.0 - x = 1.0\ \text{g}$

Total no. of moles of $CO_2 = \dfrac{1.0}{100.0} + \dfrac{1.0}{84.0} = 0.022$

$= 0.022 \times 22.4\ \text{L} = 492.8\ \text{mL}$

24. $2NaHCO_3 \xrightarrow{150^\circ C} Na_2CO_3 + CO_2 + H_2O$

$$\frac{n_{NaHCO_3}}{n_{CO_2}} = \frac{2}{1}$$

$$n_{NaHCO_3} = 2n_{CO_2} = 2 \times \frac{112}{22400} = 0.01 \text{ mole}$$

$$W_{NaHCO_3} = 0.01 \times 84 = 0.84 \text{ g}$$

$$W_{Na_2CO_3} = 1.00 - 0.84 = 0.16 \text{ g}$$

$$\% \ Na_2CO_3 = 16$$

25. $n_{CO_2} = \frac{pV}{RT} = \frac{(1 \text{ atm})(0.410 \text{ L})}{(0.082 \text{ L atm mol}^{-1} \text{ K}^{-1})(300 \text{ K})} = 0.0167 \text{ mol}$

1 mol of CO_2 accounts for 1 mol of $CaCO_3$ = 100 g of $CaCO_3$

0.0167 mol of CO_2 = 1.67 g of $CaCO_3$

Percentage purity of $CaCO_3 = \frac{1.67}{2.00} \times 100 = 83.5$

26. $[MnO_2 + 4HCl \longrightarrow MnCl_2 + 2H_2O + Cl_2] \times 3$

$3Cl_2 + 6NaOH \longrightarrow 5NaCl + NaClO_3 + 3H_2O$

$6NaOH \equiv 3MnO_2$

$6 \times 40 \text{ g} = 3 \times 87 \text{ g}$

3 mol of MnO_2 accounts for 12 mol of HCl and 6 mol of NaOH.

$\frac{60}{40}$ mol of NaOH accounts for 0.75 mol of MnO_2

$= 0.75 \text{ mol} \times 87 \text{ g mol}^{-1}$

$= 65.25 \text{ g}$

30. $C_nH_{3n}O_m(g) + \left(n + \frac{3}{4}n - \frac{m}{2}\right) O_2(g) \longrightarrow nCO_2(g) + \frac{3}{2}n \ H_2O(l)$

Contraction of volume $= 1 + n + \frac{3}{4}n - \frac{m}{2} - n = \left(1 + \frac{3}{4}n - \frac{m}{2}\right)$

31. $C_xH_yO_z(g) + \left(x + \frac{y}{4} - \frac{z}{2}\right) O_2(g) \longrightarrow xCO_2(g) + \frac{y}{2} H_2O(l)$

10.0 mL $\quad 10\left(x + \frac{y}{4} - \frac{z}{2}\right)$ mL $\quad$ 10 x mL $\quad$ zero

Volume of CO_2 produced $= 10x = 20 \Rightarrow x = 2$

33. $\underset{20.0 \text{ L}}{CH_4(g)} + \underset{40.0 \text{ L}}{2O_2(g)} \longrightarrow CO_2(g) + 2H_2O(l)$

20.8 L of $O_2 \equiv$ 100.0 L of air

40.0 L of $O_2 \equiv$ 192.0 L of air

36. $$\underset{\text{mL}\longrightarrow 30.0}{C_xH_y(g)} + \underset{30.0\left(x+\frac{y}{4}\right)}{\left(x+\frac{y}{4}\right)O_2(g)} \longrightarrow \underset{30.0x}{xCO_2(g)} + \frac{y}{2}H_2O(l)$$

According to the question $30.0\,x = 60.0 \Rightarrow x = 2$

and $30.0\left(x+\frac{y}{4}\right)O_2$ mL $= 90.0$ mL O_2

or $y = 4$

Therefore, the molecular formula of hydrocarbon $= C_2H_4$.

43. $$Na/Hg + \underset{2\text{ mol}}{2HCl(g)} \longrightarrow 2NaCl + \underset{1\text{ mol}}{H_2} + 2Hg$$

Contraction in volume $= 50.0 - 42.5 = 7.5$ mL of $H_2(g)$

1 mol of $H_2(g) \equiv 2$ mol of HCl(g)

7.5 mL of $H_2(g) \equiv 15$ mL of HCl(g)

Volume of $H_2 = 50.0 - 15.0 = 35.0$ mL

Volume of H_2 in 100.0 mixture $= \dfrac{100 \times 35}{50} = 70.0$ mL

44. The reaction is

$$C_xH_yN_z(g) + \left(x+\frac{y}{4}\right)O_2(g) \longrightarrow xCO_2(g) + \frac{y}{2}H_2O(l) + \frac{1}{2}zN_2(g)$$

45. The reaction is

$$C_xH_yS_z(g) + \left(x+\frac{y}{4}+z\right)O_2(g) \longrightarrow xCO_2(g) + \frac{y}{2}H_2O(g) + zSO_2(g)$$

50. The reaction is

$$\underset{\substack{2\text{ Vol}\\40.0\text{ mL}}}{2CO(g)} + \underset{\substack{1\text{ Vol}\\20.0\text{ mL}}}{O_2(g)} \longrightarrow \underset{\substack{2\text{ Vol}\\40.0\text{ mL}}}{2CO_2(g)}$$

Volume of CO(g) that reacts = 40.0 mL

Volume of $CO_2(g)$ formed = 40.0 mL

Volume of CO(g) removed after treatment with KOH

= 50 mL – 40 mL = 10.0 mL

❑

7

The Liquid State

• *Type 1* •

Choose the correct option. Only one option is correct.

1. Calculate the radius of a capillary tube if water rises to a height of 12.5 cm within it, assuming the angle of contact between water and glass to be 0° ($g = 10\ \text{m s}^{-2}$, $\rho = 1 \times 10^3\ \text{kg m}^{-3}$).

(a) 0.22 mm (b) 0.18 mm (c) 0.11 mm (d) 0.44 mm

2. Which of the following statements is correct?

(a) Surface tension is the energy per unit area of a free liquid surface.

(b) The unit of surface tension is N m^{-2} and its dimensions are $ML^{\circ}T^{-1}$.

(c) If a soap bubble is filled with more air, the pressure inside it increases.

(d) The angle of contact between a solid and a liquid is a property of the shape of the solid.

3. When a glass plate is immersed in mercury, the surface near the plate

(a) becomes concave

(b) is depressed

(c) is flat

(d) is first concave and then depressed

4. The dimensions $ML^{\circ}T^{-2}$ correspond to

(a) coefficient of viscosity (b) moment of inertia

(c) surface tension (d) surface area

5. There is a depression in the surface of the liquid in a capillary when

(a) the cohesive force is smaller than the adhesive force

(b) the cohesive force is greater than the adhesive force

(c) there is an equilibrium between the cohesive and the adhesive force

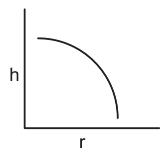
(d) none of these is true

6. A soap bubble of radius r is filled with air until the radius is doubled. If the surface tension of the soap solution is S, the work done in the process is

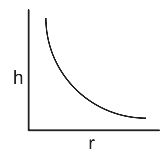
(a) $16\pi r^2 S$ (b) $4\pi r^2 S$ (c) $24\pi r^2 S$ (d) $12\pi r^2 S$

7. Which of the following correctly represents the relation between capillary rise h and capillary radius r?

(a)



(b)



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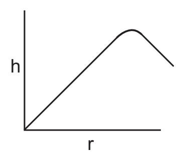

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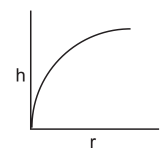


8. What is the excess pressure inside a spherical soap bubble of radius 5 cm if the surface tension of the soap film is 3.5×10^{-2} N m^{-1}?

(a) 2.8 Pa (b) 1.4 Pa

(c) 5.6 Pa (d) 11.2 Pa

9. Which of the following will happen when two soap bubbles of radius r_1 and r_2 ($r_2 > r_1$) are connected by a piece of tubing?

(a) Both bubbles will collapse.

(b) The bubbles will change in size.

(c) The bubbles will not change in size.

(d) The angle of contact will decrease.

10. When soap is added to water,

(a) the angle of contact will increase

(b) the surface tension of water will increase

(c) the angle of contact will decrease

(d) nothing will happen

11. The radius of a soap bubble is 5 cm. The surface tension of the soap film is 3.5×10^{-2} N m^{-1}. What is the work done in blowing the bubble?

(a) 4.4×10^{-2} J (b) 1.1×10^{-2} J

(c) 1.1×10^{-3} J (d) 2.2×10^{-2} J

12. Consider the relation

$$\ln \frac{p}{p_0} = \frac{2SM}{PRT} \times \frac{1}{r},$$

where p_0 and p are the vapour pressures over the liquid in bulk and over a curved surface respectively, the radius of curvature being r. Choose the correct option from among the following.

(a) The smaller the droplet of a liquid, the higher is its vapour pressure.
(b) The bigger the droplet of a liquid, the higher is its vapour pressure.
(c) The smaller the droplet of a liquid, the lower is its vapour pressure.
(d) None of these

13. When water is in contact with a waxed glass surface, the angle of contact will

(a) be zero
(b) be greater than 90°
(c) be less than 90°
(d) depend on the amount of wax

14. Surface tension does not vary with

(a) temperature
(b) vapour pressure
(c) the size of the surface
(d) concentration

15. The surface tension of $CHCl_3$ at 20°C is 27.4×10^{-3} N m^{-1}. The density of H_2O at 20°C is 0.9982 kg m^{-3} and that of $CHCl_3$ at the same temperature is 1.595 kg m^{-3}. If the rise of $CHCl_3$ and water in a capillary tube of a certain diameter is 2.33 cm and 9.9 cm respectively, calculate the surface tension of water.

(a) 82.76×10^{-3} N m^{-1}
(b) 72.86×10^{-3} N m^{-1}
(c) 78.68×10^{-3} N m^{-1}
(d) 68.72×10^{-3} N m^{-1}

16. Among the following molecules, which has the least surface tension?

(a) Benzene
(b) Acetic acid
(c) Diethyl ether
(d) Chlorobenzene

17. The film of a soap bubble has a

(a) small thickness and there is air both inside and outside the film
(b) small thickness and there is no air inside and outside the film
(c) large thickness and there is air only inside the film
(d) small thickness and there is air only outside the film

18. The pressure inside a soap bubble is

(a) greater than that outside by an amount $2S/R$ (S = surface tension and R = radius of bubble)
(b) less than that outside by an amount $4S/R$

(c) greater than that outside by an amount $4S/R$

(d) less than that outside by an amount $2S/R$

19. For which of the following pairs is the angle of contact the maximum?

(a) Water with glass (b) Water with paraffin

(c) Methylene iodide with glass (d) Mercury with glass

20. A capillary tube of radius 0.20 mm is dipped vertically in water. Calculate the height of the water column raised in the capillary tube (surface tension of water $= 0.075$ N m^{-1}, density of water $= 1.0 \times 10^3$ kg m^{-3}, $g = 10$ m s^{-2}).

(a) 10.0 cm (b) 17.5 cm

(c) 7.5 cm (d) 5.5 cm

21. A 5 cm–long needle is floating on water. What can be the maximum mass of the needle (surface tension of water $= 0.075$ N m^{-1}, $g = 10$ m s^{-2})?

(a) 0.75 g (b) 1.25 g

(c) 0.50 g (d) 1.00 g

22. When dipped in a liquid vertically, a capillary tube records a rise of 5 cm. When the tube is held in the liquid inclined at an angle of 45° to the vertical, the approximate length of the tube up to which the liquid rises is

(a) 9.0 cm (b) 8.0 cm

(c) 7.0 cm (d) 10.0 cm

23. The surface tension of a soap solution is 30×10^{-3} N m^{-1}. The work done in stretching a bubble of this solution of surface area 5 cm × 5 cm, to an area of 10 cm × 10 cm, is

(a) 4.5×10^{-4} J (b) 6.0×10^{-4} J

(c) 4.5×10^{-5} J (d) 7.5×10^{-4} J

24. Calculate the force exerted by water by across a line of length 10 cm drawn along the surface (surface tension of water $= 0.075$ N m^{-1}).

(a) 7.5×10^{-3} N (b) 7.5×10^{-4} N

(c) 7.5×10^{-2} N (d) 7.5×10^{-3} N

25. Which of the following factors is responsible for surface tension?

(a) Symmetrical force distribution in the liquid.

(b) Asymmetrical force distribution in the liquid.

(c) The symmetrical force distribution in solid.

(d) All of these.

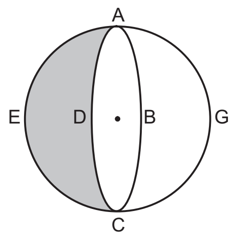
26. A small drop of liquid takes a nearly spherical shape, because

(a) for a given volume, a sphere assumes the smallest surface area

(b) for a given volume, a sphere assumes the smallest surface tension

(c) the drop has a symmetrical distribution of force
(d) the drop has the least adsorption power

27. Imagine a diametric cross-section ABCD of the liquid drop in the figure, which divides it into two hemispheres. The surfaces of the two hemispheres touch each other along the periphery ABCD.



The forces acting on the surface are
(a) F_1 due to the surface tension of the surface ABCDG in contact
(b) F_2 due to the air outside the surface ABCDE
(a) F_3 due to the liquid inside the surface ABCDE
(d) all of these

28. For the figure associated with Q.27
(a) $F_1 + F_2 + F_3 = 0$ (b) $F_1 + F_2 = F_3$
(c) $F_1 - F_2 = F_3$ (d) $F_1 = F_2 + F_3$

29. Which of the following statements is correct?
(a) The formation of a water droplet is exothermic and the breaking up of one endothermic.
(b) The formation of a water droplet is endothermic and the breaking up of one exothermic.
(c) The formation as well as the breaking up of a water droplet are exothermic.
(d) None of these.

30. If two soap bubbles of different radii are connected by a tube,
(a) the angle of contact between the soap bubbles and water decreases
(b) the surface energy of the system becomes zero
(c) air flows from the smaller to the bigger bubble
(d) the total pressure of the system remains the same

31. Bernoulli's principle is a consequence of the law of conservation of
(a) angular momentum (b) mass
(c) energy (d) momentum

32. The viscous force acting between two layers of a liquid may be worked out from the formula $\frac{F}{A} = -\eta \frac{dv}{dx}$, where the symbols have their usual meanings. *F/A* is called

(a) tangential stress (b) tangential volume

(c) density stress (d) bulk modulus

33. For laminar flow, all the particles of the liquid move parallel to the tube, and the velocity increases regulary from

(a) zero at the wall to maximum at the wall

(b) zero at the wall to maximum at the centre

(c) $-\infty$ at the wall to ∞ at the centre

(d) ∞ at the wall to $-\infty$ at the centre

34. The relation betwen turbulent and laminar flow is provided by the Reynolds number, which is equal to

(a) $\frac{2Rv\rho}{\eta}$ (b) $2\eta\frac{Rv}{\rho}$

(c) $\frac{Rv\rho}{\eta}$ (d) $2\eta\frac{\rho}{rv}$

where R = radius of capillary tube, v = velocity of liquid, ρ = density of liquid, η = viscosity of liquid.

35. When a body falls through a viscous medium, its velocity

(a) first increases and then decreases

(b) first increases and then becomes constant, and this constant velocity is called critical velocity

(c) first increases and then becomes constant, and this velocity is called terminal velocity

(d) increases continuously

36. A wooden plate of area 5 m^2 floating on the surface of a river is made to move horizontally with a speed of 1 m s^{-1} by applying a tangential force. If the river is 1 m deep and the water in contact with the plate is stationary, calculate the tangential force (viscosity = 10^{-3} poise).

(a) 5.0×10^{-2} N (b) 5.0×10^{-4} N

(c) 5.0×10^{-6} N (d) 5.0×10^{-3} N

37. The SI unit and dimensions of the coefficient of viscosity are respectively

(a) $Ns^{-1}m^{-1}$ and $ML^{-2}T^{-2}$ (b) Nsm^{-2} and $ML^{-1}T^{-1}$

(c) $Ns^{-2}m^{-2}$ and $ML^{-1}T^{-1}$ (d) $Ns^{-1}m^{-2}$ and $ML^{-2}T^{-1}$

38. Which of the following molecules has the highest viscosity?

(a) Acetone (b) Benzene
(c) Ethanol (d) Carbon tetrachloride

39. Which of the following statements is correct?

(a) The viscosities of most liquids decrease with increasing temperature, and those of gases increase with temperature.

(b) The viscosities of most liquids increase with temperature, and those of gases decrease with increasing temperature.

(c) The viscosities of liquids as well as gases decrease with increase in temperature.

(d) The viscosities of liquids as well as gases increase with increase in temperature.

40. The reciprocal of viscosity is called

(a) resistance (b) Reynolds number
(c) fluidity (d) surface tension

41. A certain volume of heptane (density $= 0.7$ g cm^{-3}) flows through a viscometer in 60 s at 20°C while the same volume of water requires 100 s at the same temperature. Calculate the absolute viscosity of heptane if that of water is 1.0×10^{-2} poise.

(a) 5.0×10^{-3} poise (b) 4.2×10^{-3} poise
(c) 6.5×10^{-3} poise (d) 1.2×10^{-3} poise

42. The viscosity of a liquid is related to the temperature by the relation

(a) $\eta = \frac{a}{T} + b$ (b) $\eta = a + bT + cT^2$
(c) $\log \eta = \frac{a}{T} + bT^2$ (d) $\ln \eta = \frac{a}{RT} + b$

43. At a high temperature, a mesomorphic milky fluid changes sharply into a clear ordinary liquid. Such a substance is known as a

(a) paracrystalline substance (b) liquid crystal
(c) transition liquid (d) colloid

44. Under the influence of an electric field, liquid crystals exhibit an optical phenomenon called dynamic scattering, in which

(a) transparent liquid crystals become opaque
(b) transparent liquid crystals become solid crystals
(c) liquid crystals become colloids
(d) liquid crystals become superconductors

• *Type 2* •

Choose the correct options. More than one option is correct.

45. Which of the following statements is correct?
   (a) The angle of contact between water and glass is 0°.
   (b) The angle of contact betwen mercury and glass is 100°.
   (c) The angle of contact between mercury and glass is 140°.
   (d) A liquid in equilibrium cannot sustain tangential stress.

46. When a capillary tube is dipped into a liquid, the liquid neither rises nor falls in the capillary. Choose the correct options.
   (a) The surface tension of the liquid must be zero.
   (b) The angle of contact must be 90°.
   (c) The surface tension may be zero.
   (d) The angle of contact may be 90°.

47. Viscosity is a property of
   (a) liquids (b) gases
   (c) solids (d) all of these

48. The viscosity of a liquid molecule depends on
   (a) the volume of the liquid (b) the temperature of the liquid
   (c) the surface area of the liquid (d) the structure of the molecule

49. Thermotropic liquid crystals may be
   (a) sematic (b) nematic
   (c) chlolestic (d) lyotropic

Answers

1. c	**2.** a	**3.** b	**4.** c	**5.** b
6. c	**7.** b	**8.** a	**9.** b	**10.** c
11. d	**12.** a	**13.** b	**14.** c	**15.** b
16. c	**17.** a	**18.** c	**19.** d	**20.** c
21. a	**22.** c	**23.** a	**24.** d	**25.** b
26. a	**27.** d	**28.** b	**29.** b	**30.** c
31. c	**32.** a	**33.** b	**34.** a	**35.** c
36. d	**37.** b	**38.** c	**39.** a	**40.** c
41. b	**42.** d	**43.** b	**44.** a	**45.** a, c, d
46. c, d	**47.** a, b	**48.** b, d	**49.** a, b, c	

Hints to More Difficult Problems

1. $2\pi r \cos\theta\, S = \pi r^2 \rho g h$

or $$r = \frac{2S}{h\rho g}\cos\theta = \frac{2 \times 0.075\ \text{N m}^{-1} \times 1}{12.5 \times 10^{-2}\ \text{m} \times 1.0 \times 10^{3}\ \text{kg m}^{-3} \times 10.0\ \text{m s}^{-2}}\cdot$$

$\therefore$ $r = 0.11$ mm.

7. From the relation $r = \dfrac{2T}{h\rho g}\cos\theta$, it is clear that $r \propto \dfrac{1}{h}\cdot$

So the plot is hyperbolic.

8. $$p = \frac{4S}{r} = \frac{4 \times 3.5 \times 10^{-2}\ \text{N m}^{-1}}{5 \times 10^{-2}\ \text{m}} = 2.8\ \text{N m}^{-2} = 2.8\ \text{Pa.}$$

11. Following Q. 8, $p = 2.8\ \text{N m}^{-2}$.

Work done $= p \times \pi r^2 = 2.8\ \text{N m}^{-2} \times \dfrac{22}{7}(0.05\ \text{m})^2$

$= 2.2 \times 10^{-2}$ J.

15. Using the equation $\dfrac{S_1}{S_2} = \dfrac{d_1 l_2}{d_2 l_1}$,

$$S_1 = \frac{(27.4 \times 10^{-3}\ \text{N m}^{-1})(0.9982\ \text{kg m}^{-3})(9.9 \times 10^{-2}\text{m})}{(1.595\ \text{kg m}^{-3})(2.33 \times 10^{-2}\ \text{m})}$$

$= 72.86 \times 10^{-3}\ \text{N m}^{-1}$.

20. $$h = \frac{2S\cos\theta}{r\rho g} = \frac{2 \times 7.5 \times 10^{-2}\ \text{N m}^{-1} \times 1}{(0.20 \times 10^{-3}\ \text{m})(10^{3}\ \text{kg m}^{-3})(10\ \text{m s}^{-2})}$$

$= 7.5$ cm.

21. $S \times 2l = mg$

or $$m = \frac{2Sl}{g} = \frac{2 \times 7.5 \times 10^{-2} \times 5.0 \times 10^{-2}}{10}$$

$= 0.75$ g.

23. Work done $= 2(A_2 - A_1) \times S$

$= 2(10 \times 10 - 5 \times 5) \times 10^{-4}\ \text{m}^2 \times 30 \times 10^{-3}\ \text{N m}^{-1}$

$= 4.5 \times 10^{-4}$ J.

27. Each hemispherical surface pulls the other due to surface tension.

30. Excess pressure $= \dfrac{4S}{r}$ or pressure $\propto \dfrac{1}{r}\cdot$

Therefore, air flows from the smaller to the bigger bubble.

35. The viscous force and the buoyant force together balance the weight, and thus the body moves with constant velocity.

36. $F = -\eta A \dfrac{dv}{dx} = 10^{-3}\ \text{N s m}^{-2} \times 5\ \text{m}^2 \times \text{m s}^{-1}\ \text{m}^{-1}$ (1 poise = N s m^{-2})

$= 5.0 \times 10^{-3}$ N.

39. For gases, viscosity $\eta = \sqrt{\dfrac{RTM}{\pi}}\ \dfrac{1}{N_A \pi \sigma^2}$ (σ = molecular diameter).

$\therefore \quad \eta \propto \sqrt{T}$.

The viscosity of gases increases with temperature.

❑

8

Oxidation–Reduction

• *Type 1* •

Choose the correct option. Only one option is correct.

1. Among the following molecules, in which does bromine show the maximum oxidation number?

(a) $Hg_2(BrO_3)_2$ (b) Br-Cl
(c) $KBrO_4$ (d) Br_2

2. A compound contains atoms A, B and C; the oxidation number of A = +2, that of B = +5 and that of C = –2. A possible formula of the compound is

(a) ABC_2 (b) $A_2(BC_3)_2$
(c) $A_3(BC_4)_2$ (d) $A_3(B_4C)_2$

3. The oxidation number of nitrogen varies from

(a) –3 to +5 (b) –1 to +1
(c) –3 to –5 (d) –5 to +1

4. Which of the following halogens do not exhibit a positive oxidation number in their compounds?

(a) I (b) Br (c) Cl (d) F

5. Iron shows an oxidation number of +1 in

(a) $[Fe(H_2O)_6]^{2+}$ (b) $Fe_4[Fe(CN)_6]_3$
(c) $[Fe(H_2O)_5NO]SO_4$ (d) $[FeBr_4]^-$

6. Phosphorus shows an oxidation number of +3 in

(a) orthophosphoric acid (b) orthophosphorous acid
(c) metaphosphoric acid (d) pyrophosphoric acid

7. A metal ion M^{3+} loses three electrons to produce another cation. The oxidation number of the metal in the cation is

(a) +3 (b) +4

(c) –3 (d) +6

8. A sample of 2.5 mol of hydrazine (N_2H_4) loses 25 mol of electrons on being converted to a new compound X. Assuming that there is no loss of nitrogen in the formation of the new compound, what is the oxidation number of nitrogen in compound X?

(a) –1 (b) –2

(c) +3 (d) +4

9. In which of the following has the oxidation number of oxygen been arranged in increasing order?

(a) $BaO_2 < KO_2 < O_3 < OF_2$ (b) $OF_2 < KO_2 < BaO_2 < O_3$

(c) $BaO_2 < O_3 < OF_2 < KO_2$ (d) $KO_2 < OF_2 < O_3 < BaO_2$

10. Which of the following agents is the most oxidizing?

(a) O_3 (b) $KMnO_4$

(c) H_2O_2 (d) $K_2Cr_2O_7$

11. Which of the following agents is the most reducing?

(a) Mg (b) Na

(c) K (d) Br_2

12. Which of the following agents is the most reducing?

(a) HNO_2 (b) H_2S

(c) H_2SO_3 (d) $SnCl_2$

13. In the reaction $3Br_2 + 6CO_3^{2-} + 3H_2O \rightarrow 5Br^- + BrO_3^- + 6HCO_3^-$,

(a) bromine is oxidized and the carbonate radical is reduced

(b) bromine is reduced and the carbonate radical is oxidized

(c) bromine is neither reduced nor oxidized

(d) bromine is both reduced and oxidized

14. In which of the following reactions will there be no change in the oxidation number of nitrogen?

(a) $HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + H_3O^+ + 2HSO_4^-$

(b) $2N_2O_4 + 2KI \rightarrow 2KNO_3 + 2NO + I_2$

(c) $2KHN_2 + N_2O \rightarrow KN_3 + KOH + NH_3$

(d) $6K_3[Fe(CN)_6] + Cr_2O_3 + 10KOH \rightarrow$

$6K_4[Fe(CN)_6] + 2K_2CrO_4 + 5H_2O$

15. Which of the following shows agents arranged in order of increasing reducing power?

(a) $Zn < Al < Mg < Na$ (b) $Al < Mg < Zn < Na$

(c) $Na < Mg < Al < Zn$ (d) $Mg < Na < Zn < Al$

16. In the reaction $2Ag + 2H_2SO_4 \rightarrow Ag_2SO_4 + 2H_2O + SO_2$, sulphuric acid acts as

(a) an oxidizing agent

(b) a reducing agent

(c) a catalyst

(d) an acid as well as an oxidant

17. In which of the following coordination compounds do the transition metals have an oxidation number of +6?

(a) $[Cr(H_2O)_4Cl_2]Cl.2H_2O$ (b) $[Fe(CO)_5]$

(c) $[(H_2O)_5Cr—O—Cr(H_2O)_5]^{4+}$ (d) $K_2[Cr(CN)_2O_2(O_2)NH_3]$

18. Which of the following has been arranged in order of increasing oxidation number of nitrogen?

(a) $NH_3 < N_2O_5 < NO < N_2$

(b) $NO_2^+ < NO_3^- < NO_2^- < N_3^-$

(c) $NH_4^+ < N_2H_4 < NH_2OH < N_2O$

(d) $NO_2 < NaN_3 < NH_4^+ < N_2O$

19. The equivalent weights of $KMnO_4$ in an acidic, a slightly alkaline or neutral and a strong alkaline medium are respectively (M = molecular weight)

(a) $M/5, M/2, M$ (b) $M/5, M/3, M/2$

(c) $M/5, M/3, M$ (d) $M/3, M, M/5$

20. The equivalent weight of $Cr_2O_7^{2-}$ in an acidic medium is

(a) $M/2$ (b) $M/3$

(c) $M/9$ (d) $M/6$

21. The equivalent weight of $Na_2S_2O_3$ in the reaction

$$2Na_2S_2O_3 + I_2 \rightarrow Na_2S_4O_6 + 2NaI$$

is

(a) M (b) $M/8$

(c) $M/0.5$ (d) $M/2$

22. In the conversion $NH_2OH \rightarrow N_2O$, the equivalent weight of NH_2OH is

(a) $M/4$ (b) $M/2$

(c) $M/5$ (d) M

23. What will be the value of the equivalent weight of $KBrO_3$ in the following ionic equation?

$$2BrO_3^- + 12H^+ + 10e \rightarrow Br_2 + 6H_2O$$

(a) $M/4$ (b) $M/6$
(c) $M/10$ (d) $M/5$

24. In the redox reaction

$$xMnO + yPbO_2 + zHNO_3 \rightarrow HMnO_4 + Pb(NO_3)_2 + H_2O$$

(a) $x=2, y=5, z=10$ (b) $x=2, y=7, z=8$
(c) $x=2, y=5, z=8$ (d) $x=2, y=5, z=5$

25. In the redox reaction

$$xKMnO_4 + yNH_3 \rightarrow KNO_3 + MnO_2 + KOH + H_2O$$

(a) $x=4, y=6$ (b) $x=8, y=3$
(c) $x=8, y=6$ (d) $x=3, y=8$

26. In the redox reaction

$$xCrCl_3 + yH_2O_2 + zNaOH \rightarrow Na_2CrO_4 + NaCl + H_2O$$

(a) $x=2, y=4, z=10$ (b) $x=2, y=6, z=5$
(c) $x=2, y=3, z=8$ (d) $x=2, y=3, z=10$

27. In the ionic reaction

$$xBrO_3^- + yCr^{3+} + zH_2O \rightarrow Br_2 + HCrO_4^- + H^+$$

(a) $x=6, y=10, z=20$ (b) $x=6, y=10, z=11$
(c) $x=6, y=10, z=22$ (d) $x=6, y=8, z=22$

28. In the ionic equation

$$xCH_3CH_2OH + yI_2 + zOH^- \rightarrow CHI_3 + HCO_2^- + I^- + H_2O$$

(a) $x=1, y=4, z=6$ (b) $x=1, y=6, z=4$
(c) $x=1, y=8, z=12$ (d) $x=1, y=8, z=8$

29. In the ethylene molecule the two carbon atoms have the oxidation numbers

(a) $-1, -1$ (b) $-2, -2$
(c) $-1, -2$ (d) $+2, -2$

30. The oxidation numbers of C-1 and C-2 in propene ($CH_3\overset{2}{C}H{=}\overset{1}{C}H_2$) are respectively

(a) $-1, -2$ (b) $-1, -1$
(c) $-2, -1$ (d) $+2, -1$

31. The oxidation number of carbon in HCOOH is

(a) $+2$ (b) -2 (c) $+4$ (d) zero

32. The oxidation number of the carboxylic carbon atom in CH_3COOH is

(a) +2 (b) +4

(c) +1 (d) +3

33. When methane is burnt in oxygen to produce CO_2 and H_2O, the oxidation number of carbon changes by

(a) –8 (b) zero

(c) +8 (d) +4

• Type 2 •

Choose the correct options. More than one option is correct.

34. The oxidation number of Cr = +6 in

(a) $FeCr_2O_4$ (b) $KCrO_3Cl$

(c) CrO_5 (d) $[Cr(OH)_4]^-$

35. The oxidation number of carbon is zero in

(a) HCHO (b) CH_2Cl_2

(c) $C_6H_{12}O_6$ (d) $C_{12}H_{22}O_{11}$

36. Which of the following are not redox reactions?

(a) $Mg + N_2 \rightarrow Mg_3N_2$

(b) $K_4[Fe(CN)_6] + H_2SO_4 + H_2O \rightarrow K_2SO_4 + CO + FeSO_4 + (NH_4)_2SO_4$

(c) $I_2 + 3Cl_2 \rightarrow ICl_3$

(d) $CuSO_4 + NH_3 \rightarrow [Cu(NH_3)_4]SO_4$

37. Which of the following are redox reactions?

(a) $NaIO_3 + NaHSO_3 \rightarrow NaHSO_4 + Na_2SO_4 + I_2 + H_2O$

(b) $FeCl_3 + K_4[Fe(CN)_6] \rightarrow KCl + Fe_4[(Fe(CN)_6]_3$

(c) $AgCl + Na_2S_2O_3 \rightarrow Na_3[Ag(S_2O_3)_2] + NaCl$

(d) $NaBiO_3 + MnSO_4 + HNO_3 \rightarrow$
$HMnO_4 + Bi(NO_3)_3 + NaNO_3 + Na_2SO_4 + H_2O$

38. Which among the following are examples of autoredox reactions?

(a) $P_4 + OH^- \rightarrow H_2PO_4^- + PH_3$ (b) $S_2O_3^{2-} \rightarrow SO_4^{2-} + S$

(c) $H_2O_2 \rightarrow H_2O + O_2$ (d) $AgCl + NH_3 \rightarrow [Ag(NH_3)_2]Cl$

39. The oxidation number of S = +6 in
(a) peroxomonosulphuric acid (Caro's acid)
(b) peroxodisulphuric acid (Marshall's acid)
(c) pyrosulphuric acid (oleum)
(d) sodium thiosulphate (hypo)

40. Which of the following have been arranged in order of decreasing oxidation number of sulphur?
(a) $H_2S_2O_7 > Na_2S_4O_6 > Na_2S_2O_3 > S_8$
(b) $SO^{2+} > SO_4^{2-} > SO_3^{2-} > HSO_4^-$
(c) $H_2SO_5 > H_2SO_3 > SCl_2 > H_2S$
(d) $H_2SO_4 > SO_2 > H_2S > H_2S_2O_8$

Answers

1. c	**2.** c	**3.** a	**4.** d	**5.** c
6. b	**7.** d	**8.** c	**9.** a	**10.** a
11. c	**12.** b	**13.** d	**14.** a	**15.** a
16. d	**17.** d	**18.** c	**19.** c	**20.** d
21. a	**22.** b	**23.** d	**24.** a	**25.** b
26. d	**27.** c	**28.** a	**29.** b	**30.** c
31. a	**32.** d	**33.** c	**34.** b, c	**35.** a, b, c, d
36. b, d	**37.** a, d	**38.** a, b, c	**39.** a, b, c	**40.** a, c

Hints to More Difficult Problems

9. $\underset{-1}{BaO_2} < \underset{-0.5}{KO_2} < \underset{0}{O_3} < \underset{+2}{OF_2}$

10. Among these, O_3 has the greatest value of standard redox potential $E°(= +2.07\text{ V})$.

13. Br_2 is reduced to Br^- (oxidation number decreases from zero to −1) and Br_2 is oxidized to BrO_3^- (oxidation number increases from zero to +5).

16. H_2SO_4 is a diprotic acid. It is also an oxidant because the oxidation number of S in the given reaction decreases from 6 to 4.

18.
	$\underline{N}H_4^+$	<	$\underline{N}_2H_4$	<	$\underline{N}H_2OH$	<	$\underline{N}_2O$
Oxidation number	−3		−2		−1		+1

19. $K\overset{+7}{Mn}O_4 \xrightarrow[\text{medium}]{\text{Acidic}} Mn^{2+} \qquad E = \dfrac{M}{7-2} = \dfrac{M}{5}$

$K\overset{+7}{Mn}O_4 \xrightarrow[\text{or weakly basic medium}]{\text{slightly alkaline}} \overset{+4}{Mn}O_2 \qquad E = \dfrac{M}{7-4} = \dfrac{M}{3}$

$K\overset{+7}{Mn}O_4 \xrightarrow[\text{medium}]{\text{strongly alkaline}} \overset{+6}{Mn}O_4^{2-} \qquad E = \dfrac{M}{7-6} = M$

20. $Cr_2O_7^{2-} + 14H^+ + 6e \longrightarrow 2Cr^{+3} + 7H_2O$

$E_{K_2Cr_2O_7} = \dfrac{M}{6}$ (no. of electrons involved = 6)

21. $2S_2O_3^{2-} \longrightarrow S_4O_6^{2-} + 2e$

$E_{Na_2S_2O_3} = \dfrac{2M}{2} = M$

22. The oxidation numbers of N in NH_2OH and N_2O are –1 and 1 respectively.

$\overset{2N=-2}{2NH_2OH} \longrightarrow \overset{2N=+2}{N_2O}$

$E = \dfrac{\text{Mol. wt.}}{\Delta\, 0.N} = \dfrac{2M}{2-(-2)} = \dfrac{2M}{4} = \dfrac{M}{2}$

23. $2BrO_3^- + 12H^+ + 10e \rightarrow Br_2 + 6H_2O$

$E_{KBrO_3} = \dfrac{\text{mol. wt.}}{\text{no. of electrons gained}} = \dfrac{2BrO_3^-}{10}$

$= \dfrac{BrO_3^-}{5} = \dfrac{KBrO_3}{5} = \dfrac{M}{5}$

where M stands for mol. wt. of $KBrO_3$

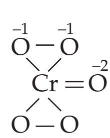
31. The oxidation no. of HCOOH = 0 or $1 + x - 4 + 1 = 0 \Rightarrow x = +2$, where x is the oxidation number of carbon in HCOOH.

33. $\overset{-4}{C}H_4(g) + 2O_2(g) \rightarrow \overset{+4}{C}O_2(g) + 2H_2O(l)$

The oxidation number of C changes by $4 - (-4) = +8$

34. The total oxidation number of $KCrO_3Cl = 0 \Rightarrow 1 + x - 6 - 1 = 0 \Rightarrow x = +6$, where x is the oxidation number of Cr.

The oxidation number of



.

Oxidation number of Cr = +6.

36. There is no change in the oxidation number of the element concerned during the course of the reaction.

38. In an autoredox reaction, an element or compound is oxidized as well as reduced.

39. $\overset{+1}{H}-\overset{-1}{O}-\overset{-1}{O}-\overset{x}{S}\,\overset{-6}{O_3}\overset{+1\,=\,0}{H}$, $x = +6$

$\overset{x}{S}\,\overset{-6}{O_3}\overset{+1}{H}-\overset{-1}{O}-\overset{-1}{O}-\overset{x}{S}\,\overset{-6}{O_3}\overset{+1\,=\,0}{H}$, $x = +6$

$\overset{+2}{H_2}\,\overset{2x}{S_2}\,\overset{-14\,=\,0}{O_7}$, $x = +6$

❑

9

Modern Concepts of Acids and Bases

• *Type 1* •

Choose the correct option. Only one option is correct.

1. Among the following Lewis acids, which has the maximum electron-acceptor character?

(a) PCl_3 (b) PCl_2R

(c) PF_3 (d) $PClR_2$

2. Which of the following is not an acid-base conjugate pair?

(a) $C_6H_5CO_2H$ and $C_6H_5CO_2^-$

(b) H_3O^+ and OH^-

(c) $CH_3NH_3^+$ and CH_3NH_2

(d) HS^- and S^{2-}

3. Which of the following species cannot exist in an aqueous solution?

(a) NO_3^- (b) NH_4^+

(c) NH_2^- (d) NH_3

4. Among the following, the strongest conjugate base is

(a) NO_3^- (b) Cl^-

(c) SO_4^{2-} (d) CH_3COO^-

5. The conjugate acid of the HPO_3^{2-} ion is

(a) PO_3^{3-} (b) $H_2PO_3^-$

(c) $H_2PO_4^-$ (d) HPO_4^{2-}

6. Of the given anions, the strongest Bronsted base is

(a) ClO^- (b) ClO_2^- (c) ClO_3^- (d) ClO_4^-

7. NH_2CH_2COOH may behave
(a) only as an acid
(b) only as a base
(c) as an acid as well as a base
(d) neither as an acid nor as a base

8. Which of the following species cannot be a Bronsted base?
(a) O^{2-} (b) CH_3^+
(c) CH_4 (d) PH_3

9. Which of the following can act as a Bronsted acid but not as a Lewis acid?
(a) OH^- (b) $AlCl_3$
(c) $FeCl_3$ (d) NH_3

10. In the formation of Al_2Cl_6, each $AlCl_3$ molecule
(a) hydrolyses
(b) acts as a Bronsted acid
(c) behaves both as a Bronsted acid and as a Bronsted base
(d) behaves both as a Lewis acid and as a Lewis base

11. Among the following, which is the strongest protonic acid?
(a) $[Fe(H_2O)_6]^{3+}$ (b) $[Fe(H_2O)_6]^{2+}$
(c) H_2O (d) BF_3

12. Among the following, which is the strongest Lewis acid?
(a) BF_3 (b) BCl_3
(c) BBr_3 (d) BI_3

13. Among the following, which is the most basic toward BMe_3?
(a) Me_3N (b) Et_3N (c) O_2 (d) SO_3

14. Among the following, which is the strongest acid?
(a) $ClO_3(OH)$ (b) $ClO_2(OH)$
(c) $SO(OH)_2$ (d) $SO_2(OH)_2$

15. Among the following, which has the highest dielectric constant?
(a) H_2O (b) H_2SO_4
(c) CH_3CH_2OH (d) CH_3COCH_3

16. Which of the following has been arranged correctly in order of increasing acidic strength?
(a) $CH_3CO_2H < O_2NCH_2CO_2H < NCCH_2CO_2H < HOCH_2CO_2H$
(b) $CH_3CO_2H < HOCH_2CO_2H < NCCH_2CO_2H < O_2NCH_2CO_2H$

(c) $HOCH_2CO_2H < NCCH_2CO_2H < CH_3CO_2H < O_2NCH_2CO_2H$

(d) $O_2NCH_2CO_2H < NCCH_2CO_2H < HOCH_2CO_2H < CH_3CO_2H$

17. Which of the following has been arranged correctly in order of increasing acidic strength?

(a) $CH_3CO_2H < HCO_2H < HO_2CCO_2H < CH_3CH_2CO_2H$

(b) $CH_3CH_2CO_2H < CH_3CO_2H < HO_2CCO_2H < HCO_2H$

(c) $HO_2CCO_2H < HCO_2H < CH_3CO_2H < CH_3CH_2CO_2H$

(d) $CH_3CH_2CO_2H < CH_3CO_2H < HCO_2H < HO_2CCO_2H$

18. Among the following, which is the strongest acid?

(a) $CH_3\underset{\displaystyle F}{\underset{|}{C}}HOH$

(b) $\underset{\displaystyle F}{\underset{|}{C}}H_2CH_2OH$

(c) $\underset{\displaystyle Cl}{\underset{|}{C}}H_2CH_2OH$

(d) CH_3CH_2OH

19. Which of the following has been arranged correctly in order of increasing basic strength?

(a) $OH^- < HC{\equiv}C^- < NH_2^- < CH_3CH_2^-$

(b) $HC{\equiv}C^- < CH_3CH_2^- < NH_2^- < OH^-$

(c) $OH^- < NH_2^- < HC{\equiv}C^- < CH_3CH_2^-$

(d) $NH_2^- < HC{\equiv}C^- < OH^- < CH_3CH_2^-$

20. Which of the following has been arranged correctly in order of increasing basic strength?

(a) $NH_3 < p\text{-}O_2NC_6H_4NH_2 < o\text{-}O_2NC_6H_4NH_2 < C_6H_5NH_2$

(b) $C_6H_5NH_2 < NH_3 < o\text{-}O_2NC_6H_4NH_2 < p\text{-}O_2NC_6H_4NH_2$

(c) $o\text{-}O_2NC_6H_4NH_2 < p\text{-}O_2NC_6H_4NH_2 < C_6H_5NH_2 < NH_3$

(d) $NH_3 < C_6H_5NH_2 < p\text{-}O_2NC_6H_4NH_2 < o\text{-}O_2NC_6H_4NH_2$

21. In a particular Lewis acid-base reaction, boric acid

(a) accepts a pair of electrons from the oxide ion present in a water molecule

(b) donates a pair of electrons to the hydrogen ion present in a water molecule

(c) accepts a pair of electrons from the hydroxide ion present in a water molecule

(d) donates a pair of electrons to the hydroxide ion present in a water molecule

22. Which negative radical of the following compounds does not exist in an aqueous solution independently?

(a) $NaCl$ (b) $NaNH_2$

(c) K_2SO_4 (d) $CaCl_2$

23. Which of the following pairs represents the strongest acid and strongest base that can exist in water?

(a) H_3O^+ and OH^- (b) NH_4^+ and NH_2^-

(c) ClO_4^- and H_2F^+ (d) NO_3^- and $HC{\equiv}C^-$

24. Which of the following is arranged in order of increasing acid strength in water?

(a) $[Al(OH)_6]^{3+} < [Fe(H_2O)_6]^{3+} < [Fe(H_2O)_6]^{2+}$

(b) $[Fe(H_2O)_6]^{3+} < [Fe(H_2O)_6]^{2+} < [Al(H_2O)_6]^{3+}$

(c) $[Fe(H_2O)_6]^{2+} < [Fe(H_2O)_6]^{3+} < [Al(H_2O)_6]^{3+}$

(d) $[Fe(H_2O)_6]^{2+} < [Al(H_2O)_6]^{3+} < [Fe(H_2O)_6]^{3+}$

25. Which of the following is not a Lewis acid-base reaction?

(a) $BrF_3 + F^- \rightarrow [BrF_4]^-$ (b) $AlCl_3 + BF_3 \rightarrow AlCl_3.BF_3$

(c) $I_2 + I^- \rightarrow I_3^-$ (d) $KH + H_2O \rightarrow KOH + H_2$

26. Which of the following is arranged in order of increasing proton affinity?

(a) $HS^- < I^- < NH_2^- < F^-$ (b) $F^- < I^- < NH_2^- < HS^-$

(c) $I^- < F^- < HS^- < NH_2^-$ (d) $NH_2^- < HS^- < F^- < I^-$

27. Which of the following is the most strongly basic in water?

(a) CO_3^{2-} (b) ClO_4^-

(c) NO_3^- (d) O^{2-}

28. Which of the following is the weakest acid in H_2SO_4?

(a) ClO_4^- (b) NO_3^- (c) HSO_4^- (d) CN^-

29. Among the following, which is the strongest Lewis acid?

(a) $B(t\text{-}Bu)_3$ (b) $BeCl_2$

(c) $B(n\text{-}Bu)_3$ (d) BF_3

30. Which of the following is the most basic towards $B(CH_3)_3$

(a) 4-CH_3C—H_4N (b) $(C_2H_5)_3N$

(c) NH_3 (d) 2-$CH_3C_5H_4N$

31. The enthalpies of reaction of trimethylboron with NH_3, CH_3NH_2, $(CH_3)_2NH$ and $(CH_3)_3N$ are –58, –74, –81 and –74 kJ mol^{-1} respectively. What is the reason for trimethylamine being out of line?

(a) Resonance stabilization
(b) Steric repulsion
(c) Solvation factor
(d) Lattice energy considerations

32. Which of the following is arranged in order of increasing acidity?

(a) $[Mn(H_2O)_6]^{2+} < [Na(H_2O)_6]^{+} < [Sc(H_2O)_6]^{3+} < [Ni(H_2O)_6]^{2+}$
(b) $[Ni(H_2O)_6]^{2+} < [Sc(H_2O)_6]^{3+} < [Na(H_2O)_6]^{+} < [Mn(H_2O)_6]^{2+}$
(c) $[Na(H_2O)_6]^{+} < [Mn(H_2O)_6]^{2+} < [Ni(H_2O)_6]^{2+} < [Sc(H_2O)_6]^{3+}$
(d) $[Sc(H_2O)_6]^{3+} < [Ni(H_2O)_6]^{2+} < [Mn(H_2O)_6]^{2+} < [Na(H_2O)_6]^{+}$

33. Among the following, which is the weakest Lewis base?

(a) CH_3^- (b) NH_2^-
(c) OH^- (d) F^-

34. H_3PO_2 and $H_4P_2O_7$ are respectively

(a) tribasic and tetrabasic acids
(b) dibasic and tetrabasic acids
(c) monobasic and tetrabasic acids
(d) tribasic and dibasic acids

35. Which of the following statements is incorrect?

(a) HNO_2 is a stronger acid than CH_3CO_2H.
(b) NO_2^- is a weaker base than CN^-.
(c) NH_2^- does not exist in an aqueous solution.
(d) NH_2^- ion exists in an aqueous solution.

36. Which of the following represents an ordered arrangement of the most acidic through amphoteric to the most basic compounds?

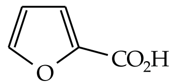
(a) $BaO < Al_2O_3 < B_2O_3 < CO_2 < SO_3 < Cl_2O_7$
(b) $Cl_2O_7 < SO_3 < CO_2 < B_2O_3 < Al_2O_3 < BaO$
(c) $Al_2O_3 < B_2O_3 < CO_2 < Cl_2O_7 < SO_3 < BaO$
(d) $SO_3 < Cl_2O_7 < B_2O_3 < CO_2 < BaO < Al_2O_3$

37. Which of the following compounds is the most likely to be amphoteric?

(a) Li_2O (b) PbO_2 (c) MgO (d) P_4O_{10}

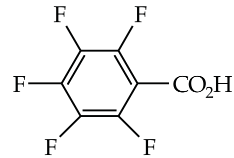
38. Which of the following carboxylic acids is the least acidic?

(a)

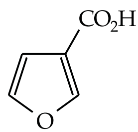


Furan-2-carboxylic acid

(b)

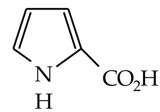


(c)



Furan-3-carboxylic acid

(d)



39. Which of the carboxylic acids is the most acidic?

(a) Acetic acid (b) Formic acid

(c) Benzoic acid (d) Cyclopentane carboxylic acid

40. A transition element forms several binary oxides, and the oxide with the metal in the

(a) highest oxidation state is the most acidic

(b) lowest oxidation state is the most acidic

(c) highest oxidation state is amphoteric

(d) highest oxidation state is basic

• *Type 2* •

Choose the correct options. More than one option is correct.

41. Which of the following cannot act as a Bronsted base?

(a) NH_3 (b) BF_3

(c) H_3O^+ (d) H_2O

42. Which of the following compounds are not bases when dissolved in water?

(a) K_2O (b) Na_2O_2

(c) NO_2 (d) Cl_2O_7

43. Which of the following compounds/ions can act as a Bronsted acid as well as a Bronsted base?

(a) HCO_3^- (b) K_2CO_3

(c) H_2SO_4 (d) $H_2PO_4^-$

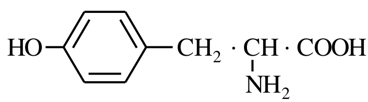
44. Which of the following acids are likely to form zwitterions?

(a) $H_2N \cdot \underset{\displaystyle CH_3}{\underset{|}{CH}} \cdot CO_2H$

(b) $HO_2C \cdot CH_2 \cdot \underset{\displaystyle NH_2}{\underset{|}{CH}} \cdot CO_2 \cdot H$

(c) $H_2N \cdot CH_2CH_2CH_2CH_2 \cdot \underset{\displaystyle NH_2}{\underset{|}{CH}} \cdot CO_2H$

(d)



45. Which of the following species can be formed in acid-base reactions as Bronsted bases as well as Bronsted acids?

(a) $[Fe(H_2O)_6]^{3+}$ (b) HPO_4^{2-} (c) HSO_4^- (d) NH_4^+

46. On the basis of Bronsted concepts, which of the following are correct?

(a) $CH_3CH_2OH + HCl \rightleftharpoons CH_3CH_2O^+H_2 + Cl^-$

(b) $CH_3CH_2OH + NH_2^- \rightleftharpoons CH_3CH_2O^+H_2 + NH^{2-}$

(c) $CH_3CO_2H + CH_3O^- \rightleftharpoons CH_3CO_2^- + CH_3OH$

(d) $CH_3CO_2H + CH_3NH_2 \rightleftharpoons CH_3COOH_2^+ + CH_3NH_2^-$

47. Which of the following statements are correct?

(a) HO^- is a stronger base than NH_2^-.

(b) H_2O is a stronger base than CH_3OH.

(c) CH_3COO^- is a stronger base than HCO_2H.

(d) A Lewis acid is a compound that can accept a pair of electrons.

48. Which of the following species can act as a Bronsted base as well as a Lewis base?

(a) NO_3^- (b) CN^- (c) NH_3 (d) BF_3

49. Which of the following are Lewis acids?

(a) $(CH_3)_3B$ (b) $:CH_2$ (c) S (d) CH_3^+

50. On the basis of the Lewis concept, which of the following are correct?

(a) $Ag^+ + 2NH_3 \rightarrow [H_3N—Ag—NH_3]^+$

(b) $Br_2 + FeCl_3 \rightleftharpoons Br—\overset{+}{Br}—\overset{-}{Fe}Cl_3$

(c) $ROH + ZnCl_2 \rightleftharpoons R\text{—}\overset{+}{O}H$ with $ZnCl_2$ bonded to O: $R\text{—}\overset{+}{O}H(ZnCl_2)$

(d) $NH_4^+ + OH^- \rightleftharpoons NH_3 + H_2O$

51. Which of the following have been arranged correctly in order of increasing acidic strength?

(a) $HF < HCl < HBr < HI$

(b) $H_3PO_2 < H_3PO_3 < H_3PO_4$

(c) $H_3PO_4 < H_2SO_4 < HClO_4$

(d) $NH_3 < PH_3 < AsH_3 < BiH_3$

52. Which of the following have been arranged correctly in order of increasing basic strength?

(a) $LiOH < NaOH < KOH < RbOH$

(b) $Al(OH)_3 < Mg(OH)_2 < NaOH$

(c) $NH_3 < NH_2OH < N_2H_4$

(d) $HF < H_2O < NH_3$

53. Which of the following have been arranged correctly in order of increasing basic strength?

(a) $C_6H_5N(CH_3)_2 < C_6H_5NHCH_3 < C_6H_5NH_2$

(b) $NH_2^- < OH^- < F^-$

(c) $(CH_3)_3N < CH_3NH_2 < (CH_3)_2NH$

(d) $NH_2OH < N_2H_4 < NH_3$

54. Which of the following salts are acidic in aqueous solutions?

(a) $(NH_4)_2SO_4$ (b) $NaHCO_3$

(c) $CuSO_4$ (d) $AgNO_3$

55. Which of the following salts are alkaline in aqueous solutions?

(a) NaCN (b) $K_4[Fe(CN)_6]$

(c) CH_3CO_2Na (d) $FeCl_3$

Answers

1. c	**2.** b	**3.** d	**4.** d	**5.** b
6. a	**7.** c	**8.** b	**9.** d	**10.** d
11. a	**12.** c	**13.** a	**14.** a	**15.** b

16. b	**17.** d	**18.** a	**19.** a	**20.** c
21. c	**22.** b	**23.** a	**24.** c	**25.** b
26. c	**27.** d	**28.** a	**29.** c	**30.** a
31. b	**32.** c	**33.** d	**34.** c	**35.** d
36. b	**37.** b	**38.** d	**39.** b	**40.** a
41. b, c	**42.** c, d	**43.** a, d	**44.** a, b, c, d	**45.** b, c
46. a, c	**47.** b, c, d	**48.** a, b, c	**49.** a, b, c, d	**50.** a, b, c
51. a, c, d	**52.** a, b, d	**53.** a, c, d	**54.** a, c, d	**55.** a, c

Hints to More Difficult Problems

4. Acetic acid is the weakest of these.

6. Among the oxyacids of chlorine, HClO is the weakest.

10. During the formation of Al_2Cl_6, one $AlCl_3$ group is an electron-pair donor and the other is an electron-pair acceptor.

12. The strengths of boron halides as Lewis acids are in the order $BBr_3 > BCl_3 > BF_3$. This order is the opposite of what is expected on steric grounds as well as from considerations of electronegatively. It can be explained in terms of boron-halogen π-bonding.

18. The compound listed first is the most acidic because the electron-withdrawing fluorine is the closest to the bond that holds the acidic hydrogen.

22. The amide ion (NH_2^-) is a stronger base than OH^- and therefore reacts completely with water as follows:

$$NH_2^-(aq) + H_2O(l) \longrightarrow NH_3(aq) + OH^-(aq)$$

For this reason the amide ion does not exist in aqueous solutions.

24. The weakest acid is the Fe^{2+} complex because of its relatively large radius and low charge. The increase of charge to +3 increases the acid strength. The greater acidity of Al^{3+} can be explained by its small radius.

25. Both the reactants are electron-deficient.

29. B(*n*-*Bu*) has no sterific effect.

30. It is easier to remove a proton from 4-methylpyridine, and the electron left behind when the proton is removed is delocalized onto the electronegative nitrogen atom. In 4-methylpyridine, the electrons can be delocalized only onto the carbon atom. So nitrogen will be a good electron-pair donor for $B(CH_3)_3$.

32. Sc^{3+} has the smallest radius.

36. Cl_2O_7 forms a strong oxoacid and alkaline earth metals form strong bases with water.

42. NO_2 and Cl_2O_7 form acids (HNO_2 and $HClO_4$) upon reacting with water.

45. HPO_4^{2-} and HSO_4^- can donate a proton to form PO_4^{3-} and SO_4^{2-} respectively. They can also accept a proton to form $H_2PO_4^{-4}$ and H_2SO_4 respectively.

❑

10

Volumetric Analysis

• *Type 1* •

Choose the correct option. Only one option is correct.

1. Calculate the equivalent weight of Na_2CO_3 when it is titrated against HCl in presence of phenolphthalein.

(a) 106 (b) 53
(c) 26.5 (d) 212

2. 5 mL of $N/50$ $Ba(OH)_2$ solution was poured into a 2.5-L flask containing some CO_2. The flask was then tightly corked. The CO_2 was completely absorbed by the $Ba(OH)_2$ solution. The percentage of CO_2 in the flask was

(a) 0.045 (b) 0.45
(c) 4.5 (d) 0.065

3. Calculate the equivalent weight of Na_2CO_3 when it is titrated against HCl in the presence of methyl orange.

(a) 5.3 (b) 53
(c) 10.6 (d) 106

4. If the mole fraction of a solute in an aqueous solution is 0.50, the molality of the solution is

(a) 1.55 (b) 0.5
(c) 55.55 (d) 5.55

5. Carbonate-free sodium hydroxide is prepared by using

(a) $NaHCO_3$ (b) $Ba(OH)_2$
(c) Na_2CO_3 (d) $BaSO_4$

6. During the first stage of titration of phosphoric acid (when the first H^+ ion is lost from H_3PO_4) against a standard NaOH solution, the indicator used is

(a) methyl orange (b) phenolphthalein
(c) 1-naphtholphthalein (d) thymolphthalein

7. During the second stage of titration of phosphoric acid (when the second H^+ ion is lost from $H_2PO_4^-$) against a standard NaOH solution, the indicator used is

(a) methyl red (b) methyl orange
(c) phenolphthalein (d) bromo-cresol green

8. $NaNO_3$ is estimated by

(a) reducing $NaNO_3$ by zinc in an alkaline medium to NH_3 which is titrated against a standard acid

(b) reducing $NaNO_3$ by zinc in an acidic medium to NaOH which is titrated against a standard acid

(c) reducing $NaNO_3$ by zinc in an alkaline medium to $NaNO_2$ which is titrated against a standard $KMnO_4$ solution

(d) none of these

9. A 15-volume sample of an H_2O_2 solution is equivalent to

(a) 5.30 N (b) 1.77 N
(c) 2.68 N (d) 7.50 N

10. 1 g of pyrolusite is made to completely react with 20 mL of 1-N oxalic acid in an H_2SO_4 medium. The percentage of the oxygen available by weight in pyrolusite is

(a) 43.5 (b) 16 (c) 8 (d) 32

11. 100 mL of $N/5$ NaOH will neutralize

(a) 0.06184 g of H_3BO_3 (b) 0.1855 g of H_3BO_3
(c) 1.2368 g of H_3BO_3 (d) 0.03092 g of H_3BO_3

12. During the titration of $KMnO_4$, the solution is made acidic with

(a) dilute H_2SO_4 (b) dilute HCl
(c) concentrated H_2SO_4 (d) concentrated HCl

13. 0.5 g of an iron wire was dissolved in 75 mL of bench H_2SO_4, and the volume was increased to 250 mL with water. 25 mL of this solution reduced 8.5 mL of of $N/10$ $KMnO_4$ solution. The amount of pure iron present was (atomic weight of Fe = 56)

(a) 0.500 g (b) 0.252 g
(c) 0.238 g (d) 0.476 g

14. Using a standard $KMnO_4$ solution, the ferric ion is estimated by reducing it with

(a) mercury (b) an $FeSO_4$ solution
(c) an $SnCl_2$ solution (d) an $HgCl_2$ solution

15. When we say that an H_2O_2 solution is a "10-volume" solution, we mean that, when fully decomposed by heat, it yields

(a) ten times its volume of oxygen measured at 273 K and 1 atmospheric pressure

(b) ten times its volume of oxygen measured at 298 K and 1 atmospheric pressure

(c) five times its volume of oxygen measured at 273 K and 10 atmospheric pressure

(d) its volume of oxygen measured at 273 K and 1 atmospheric pressure

16. Hydrazine reacts with KIO_3 in a concentrated HCl medium. This reaction may be represented as

$$N_2H_4 + IO_3^- + 2H^+ + Cl^- \longrightarrow ICl + N_2 + 3H_2.$$

Choose the correct option.

(a) 1 mL of 0.25-M $KIO_3 \equiv 0.0008013$ g of $N_2H_4 \equiv 0.003253$ g of $N_2H_4.H_2SO_4$

(b) 1 mL of 0.25-M $KIO_3 \equiv 0.008013$ g of $N_2H_4 \equiv 0.03254$ g of $N_2H_4.H_2SO_4$

(c) 1000 mL of 1-M $KIO_3 \equiv 0.032$ g of $N_2H_4 \equiv 0.130$ g of $N_2H_4.H_2SO_4$

(d) 1 mL of 0.5-M $KIO_3 \equiv 0.016$ g of $N_2H_4 \equiv 0.0065$ g of $N_2H_4.H_2SO_4$

17. In the estimation of hydroxylamine based upon the reduction of ferric solutions in the presence of H_2SO_4, by boiling and subsequent titration in the cold condition with a standard $KMnO_4$ solution, which of the following reactions will occur.

(a) $NH_2OH + Fe^{3+} \rightarrow N_2H_4 + Fe^{2+} + H^+ + H_2O$

(b) $NH_2OH + Fe^{3+} \rightarrow N_2O + Fe^{2+} + H^+ + H_2O$

(c) $NH_2OH + Fe^{3+} \rightarrow NO_2 + Fe^{2+} + H^+ + H_2O$

(d) $NH_2OH + Fe^{3+} \rightarrow NH_3 + Fe^{2+} + H^+ + H_2O$

18. Copper is estimated iodometrically by titrating a solution of copper sulphate against a standard solution of

(a) potassium permanganate
(b) potassium iodate
(c) potassium persulphate
(d) sodium thiosulphate

19. A sample of 1.0 g of solid Fe_2O_3 of 80% purity is dissolved in a moderately concentrated HCl solution which is reduced by zinc dust. The resulting solution required 16.7 mL of a 0.1-M solution of the oxidant. Calculate the number of electrons taken up by the oxidant (the atomic weights of Fe and O are 56 and 16 respectively).

(a) 2
(b) 4
(c) 6
(d) 5

20. What volume of approximately 1.00 M HCl should be mixed with how much 0.25 M HCl in order to prepare 1.00 L of 0.50 M HCl?

(a) 667 mL and 333 mL (b) 667 mL and 333 mL

(c) 500 mL and 500 mL (d) 250 mL and 750 mL

21. What volume of 0.25 M $Ca(NO_3)_2$ will contain 2.0 mol of nitrate ion?

(a) 0.5 L (b) 1.0 L

(c) 1.5 L (d) 2.0 L

22. What volume of 0.1 M H_2SO_4 will be required to produce 17.0 g of H_2S by the reaction $5H_2SO_4 + 8NaI \rightarrow 4Na_2SO_4 + 4I_2 + H_2S + 4H_2O$?

(a) 70.0 L (b) 50.0 L

(c) 25.0 L (d) 5.0 L

23. The relation between molarity (M) and molality (m) is given by (ρ = density of solution, M_1 = molecular weight of solute)

(a) $m = \dfrac{1000\,M}{1000\,\rho - M_1}$ (b) $m = \dfrac{1000\,\rho\,M}{1000\,\rho - MM_1}$

(c) $m = \dfrac{1000\,MM_1}{1000\,\rho - MM_1}$ (d) $m = \dfrac{1000\,M}{1000\,\rho - MM_1}$

24. The number of iodine atoms present in 50 mL of a 0.1 M KI solution is

(a) 6×10^{23} (b) 12×10^{23}

(c) 3×10^{21} (d) 6×10^{22}

25. Calculate the mass of anhydrous HCl in 10 mL of concentrated HCl (density = 1.2 g/mL^{-1}) which has 37% HCl by weight.

(a) 4.44 g (b) 4.44 mg

(c) 4.44×10^{-3} g (d) 0.444 μg

26. What volume of 0.4 M $FeCl_3.6H_2O$ will contain 600 mg of Fe^{3+} (atomic weight of Fe = 55.85)?

(a) 49.85 mL (b) 26.85 mL

(c) 147.55 mL (d) 87.65 mL

27. 125 mL of 10% NaOH (*w/V*) is added to 125 mL of 10% HCl (*w/V*). The resultant solution becomes

(a) alkaline (b) strongly alkaline

(c) acidic (d) neutral

28. A sample of $Na_2CO_3.H_2O$ weighing 1.24 g is added to 200 mL of a 0.1 N H_2SO_4 solution. The resulting solution is

(a) acidic (b) strongly acidic

(c) alkaline (d) neutral

29. 0.2 mol of HCl and 0.1 mol of barium chloride were dissolved in water to produce a 500 mL solution. The molarity of the Cl^- ions is

(a) 0.06 M (b) 0.09 M

(c) 0.12 M (d) 0.80 M

30. Equal volumes of 0.50 M HCl, 0.25 M NaOH and 2.75 M NaCl are mixed. The molarity of the NaCl solution is

(a) 0.75 M (b) 1.00 M

(c) 0.50 M (d) 2.00 M

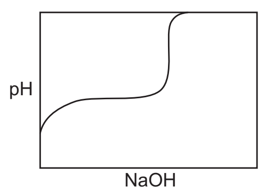
31. 25 mL of 2 N HCl, 50 mL of 4 N HNO_3 and x mL of 5 M H_2SO_4 are mixed together and the total volume is made up to 1 L with water. 50 mL of this acid mixture exactly neutralizes 25 mL of a 1 N Na_2CO_3 solution. The value of x is

(a) 25 mL (b) 40 mL

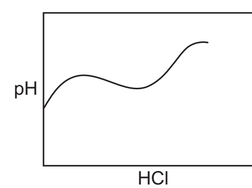
(c) 60 mL (d) 50 mL

32. Which of the following indicates the titration of a weak base against a strong acid?

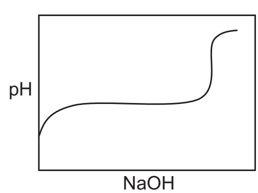
(a)



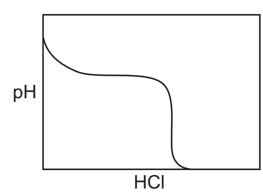
(b)



(c)

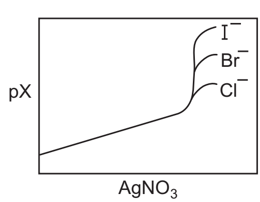


(d)

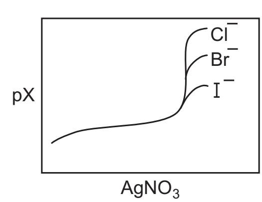


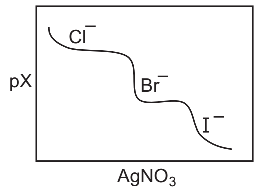
33. Which of the following represents the titration curve for 100 mL of 0.1 M Cl^-, Br^- and I^- solutions against 0.1 M $AgNO_3$?
($X = Cl^-, Br^-, I^-$)

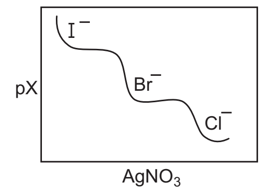
(a)



(b)



(c) 

(d) 

34. Which of the following processes are used to remove temporary as well as permanent hardness in water?

(a) Boiling the water

(b) Making the water react with lime

(c) Treating the water with a $Ca(OH)_2$ solution and then with HCl

(d) Boiling the water with a calculated quantity of Na_2CO_3 solution and then with HCl

35. 1 L of tap water contains 20 mg of Ca^{2+} and 12 mg of Mg^{2+} ions. What is the volume of a 2 N Na_2CO_3 solution required to soften 1000 L of tap water?

(a) 100 L (b) 1 L

(c) 1000 L (d) 10 L

36. The most suitable indicator for the titration of a mixture of HCl and H_3PO_4 against NaOH will be

(a) methyl red and methyl orange

(b) methyl red and bromothymol blue

(c) methyl orange and phenolphthalein

(d) only methyl red

37. How many grams of copper will be replaced in 2 L of a 1.50 M $CuSO_4$ solution if the latter is made to react with 27.0 g of aluminium? (Cu = 63.5, Al = 27.0)

(a) 190.50 g (b) 95.25 g

(c) 31.75 g (d) 10.65 g

38. The pH range of an indicator is given by

(a) $pH = pK + 1$ (b) $pH = pK - 1$

(c) $pH = pK$ (d) $pH = pK \pm 1$

39. The strength of a mixture of HCl and H_2SO_4 is 0.1 N. On treatment with an excess of an $AgNO_3$ solution, 20 mL of this acid mixture gives 0.1435 g of AgCl. The strength of the H_2SO_4 is

(a) $24.5\ g\ L^{-1}$ (b) $2.45\ g\ L^{-1}$

(c) $49\ g\ L^{-1}$ (d) $4.9\ g\ L^{-1}$

40. To prepare a 0.5 M KCl solution from 100 mL of 0.40 M KCl, we need to add

(a) 0.75 g of KCl
(b) 20 mL of water
(c) 0.1 mol of KCl
(d) 0.2 mol of KCl

41. Which of the following indicators is used in the titration of a weak acid with a strong base?

(a) Methyl red
(b) Cresol red
(c) Phenolphthalein
(d) Methyl orange

42. Which of the following indicators are used in the titration of $KMnO_4$ against sodium oxalate in an acidic medium?

(a) Starch
(b) Phenolphthalein
(c) $K_2Cr_2O_7$
(d) No indicator is necessary

43. Which of the following indicators (nature indicated) are used during the titration of $Na_2S_2O_3$ with I_2?

(a) Starch (external indicator)
(b) Starch (internal indicator)
(c) K_2CrO_4 (external indicator)
(d) Fluorescein (internal indicator)

44. Consider a pure H_2SO_4 (98% by weight) solution having a specific gravity of 1.8. The molarity of the H_2SO_4 is

(a) 36 M
(b) 18 M
(c) 9 M
(d) 72 M

45. Why are strong acids generally used as standard solutions in acid-base titrations?

(a) If we use them, the pH at the equivalence point will always be 7.0.
(b) They can be used to titrate strong as well as weak bases.
(c) Strong acids form more stable solutions than weak bases do.
(d) Salts of strong acids and strong bases do not hydrolyse.

46. What is the volume of a sample of 0.250 M HNO_3 that would react with 50 mL of 0.20 M K_2CO_3 in the following reaction?

$$K_2CO_3 + 2HNO_3 \longrightarrow 2KNO_3 + H_2O + CO_2$$

(a) 40 mL
(b) 10 mL
(c) 20 mL
(d) 80 mL

47. The mole fraction of a given sample of I_2 in C_6H_6 is 0.2. The molality of I_2 in C_6H_6 is

(a) 0.32
(b) 3.2
(c) 0.032
(d) 0.48

48. Calculate the molality of a 1-L solution of 90% H_2SO_4 (w/v), given that the density of the solution is 1.80 g mL^{-1}.

(a) 10.2 (b) 8.6
(c) 1.02 (d) 10.8

49. A sample of H_2SO_4 (density 1.8 g mL^{-1}) is 90% by weight. What is the volume of the acid that has to be used to make 1 L of 0.2 M H_2SO_4?

(a) 16 mL (b) 10 mL
(c) 12 mL (d) 18 mL

50. Calculate the weight of the $BaCl_2$ needed to prepare 250 mL of a solution having the same concentration of Cl^- ions as that in a solution of KCl of concentration 80 g L^{-1} (Ba = 137.4, Cl = 35.5).

(a) 27.92 g (b) 14.50 g
(c) 22.52 g (d) 11.46 g

51. A solution of NaOH is prepared by dissolving 4.0 g of NaOH in 1 L of water. Calculate the volume of the HCl gas at stp that will neutralize 50 mL of this solution.

(a) 224 mL (b) 56 mL
(c) 112 mL (d) 448 mL

52. How many millilitres of 0.1 M H_2SO_4 must be added to 50 mL of 0.1 M NaOH to give a solution that has a concentration of 0.05 M in H_2SO_4?

(a) 400 mL (b) 50 mL
(c) 200 mL (d) 100 mL

53. You are given 500 mL of 2 N HCl and 500 mL of 5 N HCl. What will be the maximum volume of 3-M HCl that you can make from these two solutions?

(a) 250 mL (b) 750 mL
(c) 500 mL (d) 1000 mL

54. A 0.492 g sample of KH_2PO_4 is titrated against a solution of 0.112 M NaOH. The volume of the base required to do this is 25.6 mL. The reaction is represented by

$$H_2PO_4^- + OH^- \longrightarrow HPO_4^{2-} + H_2O \qquad (P = 31)$$

The percentage purity of KH_2PO_4 is

(a) 46.32 (b) 79.32
(c) 78.42 (d) 88.45

55. 50 mL of a solution of Na_2CO_3 neutralizes 49.35 mL of 4.0 N HCl. The reaction is represented by

$$CO_3^{2-} + 2H^+ \longrightarrow CO_2 + H_2O$$

The density of this Na_2CO_3 solution is 1.25 g mL^{-1}. The percentage of Na_2CO_3 in it is

(a) 47.7 (b) 37.7 (c) 26.7 (d) 16.7

56. 0.70 g of impure $(NH_4)_2SO_4$ was boiled with 100 mL of a 0.2 N NaOH solution till all the $NH_3(g)$ evolved. The remaining solution was diluted to 250 mL. 25 mL of this solution was neutralized using 10 mL of a 0.1 N H_2SO_4 solution. The percentage purity of the $(NH_4)_2SO_4$ sample is

(a) 94.3 (b) 50.8 (c) 47.4 (d) 79.8

57. 7.45 g of an alkali-metal chloride was dissolved in water to make 1 L of solution. 50 mL of this solution required 10 mL of a 0.2 N $AgNO_3$ solution for complete precipitation. Identify the alkali metal.

(a) Na (b) Li
(c) K (d) Cs

58. HCl solutions in A and B alone have concentrations of 5N and 2N respectively. The volumes of solutions of A and B required to make 1 L of a 4 N HCl solution in A and B together will be

(a) $\frac{1}{4}$ L of A + $\frac{3}{4}$ L of B (b) $\frac{2}{3}$ L of A + $\frac{1}{3}$ L of B
(c) $\frac{1}{3}$ L of A + $\frac{2}{3}$ L of B (d) $\frac{1}{5}$ L of A + $\frac{1}{2}$ L of B

59. $KMnO_4$ reacts with oxalic acid according to the equation

$$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \longrightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

Here 20 mL of 0.1-M $KMnO_4$ is equivalent to

(a) 120 mL of 0.25 M $H_2C_2O_4$ (b) 150 mL of 0.10 M $H_2C_2O_4$
(c) 50 mL of 0.10 M $H_2C_2O_4$ (d) 50 mL of 0.20 M $H_2C_2O_4$

60. What would be the normality of a 0.1 M $K_2Cr_2O_7$ solution used as a precipitating agent for Pb^{2+}?

(a) 0.1 N (b) 0.6 N (c) 0.4 N (d) 0.2 N

61. A solution of H_2O_2 is titrated against a solution of $KMnO_4$. The reaction is

$$2MnO_4^- + 5H_2O_2 + 6H^+ \longrightarrow 2Mn^{2+} + 5O_2 + 8H_2O$$

If it requires 46.9 mL of 0.145 M $KMnO_4$ to oxidize 20.0 g of H_2O_2, the mass percentage of H_2O_2 in this solution is

(a) 2.9 (b) 29 (c) 21 (d) 4.9

• Type 2 •

Choose the correct options. More than one option is correct.

62. Which of the following are primary standard substances?

(a) $Na_2CO_3.10H_2O$ (b) NaOH
(c) $Na_2B_4O_7.10H_2O$ (d) $KMnO_4$

63. Which of the following statements are correct?

(a) The point at which an equivalent amount of the titrant is added is called the equivalence point.

(b) The point at which the reaction is observed to be complete is called the end point.

(c) At the end point of a reaction there is no change in the properties of the solution.

(d) At the equivalence point of a reaction the stoichiometric amount of the titrant is not added.

64. 100 mL of a 0.1 M SO_4^{2-} solution is

(a) 10 millimoles (b) 5 millimoles

(c) 20 milliequivalents (d) 40 milliequivalents

65. Which of the following will be present in the solution formed when 50 mL of 0.1 M HCl is mixed with 50 mL of 0.1 M NaOH?

(a) 4.5 m mol of H^+ (b) 0.05 m mol of OH^-

(c) 0.05 M NaCl (d) 10^{-7} M of H^+ ion

66. Which of the following statements are correct?

(a) During the titration of a strong acid against a strong base, the pH at the equivalence point will be neutral.

(b) During the titration of a weak acid against a strong base, the pH at the equivalence point will be alkaline.

(c) During the titration of a weak base with a strong acid, the pH at the equivalence point will be acidic.

(d) During the titration of a weak acid against a weak base, the pH at the equivalence point will be neutral.

67. During the titration of a mixture of Na_2CO_3 and $NaHCO_3$ against HCl,

(a) phenolphthalein is used to detect the first end point

(b) phenolphthalein is used to detect the second end point

(c) methyl orange is used to detect the second end point

(d) methyl red is used to detect the first end point

68. 1 mol of H_2SO_4 will exactly neutralize

(a) 2 mol of ammonia (b) 1 mol of $Ba(OH)_2$

(c) 0.5 mol of $Ba(OH)_2$ (d) 2 mol of KOH

69. At the end point there is a sharp change of colour in the indicator. This happens because the

(a) pH at the end point changes sharply

(b) structure of the indicator changes

(c) colour of indicator is adsorbed by water

(d) dissociation constants of acids and bases differ by ten

70. '20 volumes' of H_2O_2 is equal to

(a) 20% H_2O_2 by mass (b) 6% H_2O_2 by mass

(c) 1.764 N (d) 3.528 N

71. A solution of $Na_2S_2O_3$ is standardized iodometrically against 0.1262 g of $KBrO_3$. This process requires 45 mL of the $Na_2S_2O_3$ solution. What is the strength of the $Na_2S_2O_3$?

(a) 0.2 M (b) 0.1 M (c) 0.05 N (d) 0.1 N

Answers

1. a	**2.** a	**3.** b	**4.** c	**5.** b
6. a	**7.** c	**8.** a	**9.** c	**10.** b
11. c	**12.** a	**13.** d	**14.** c	**15.** a
16. a	**17.** b	**18.** d	**19.** c	**20.** a
21. b	**22.** c	**23.** d	**24.** c	**25.** a
26. b	**27.** c	**28.** d	**29.** d	**30.** b
31. a	**32.** d	**33.** a	**34.** d	**35.** b
36. b	**37.** b	**38.** d	**39.** b	**40.** a
41. c	**42.** d	**43.** a	**44.** b	**45.** b
46. d	**47.** b	**48.** a	**49.** c	**50.** a
51. c	**52.** d	**53.** b	**54.** b	**55.** d
56. a	**57.** c	**58.** c	**59.** c	**60.** d
61. a	**62.** a, c	**63.** a, b	**64.** a, c	**65.** c, d
66. a, b, c	**67.** a, c	**68.** a, b, d	**69.** a, b	**70.** b, d
71. b, d				

Hints to More difficult Problems

1. With phenolphthalein as indicator the only action is the conversion of the sodium carbonate to the bicarbonate.

$$\underset{106\text{ g}}{Na_2CO_3} + \underset{36.5\text{ g}}{HCl} \rightarrow NaCl + NaHCO_3$$

Equivalent weight of $Na_2CO_3 = \frac{106}{1} = 106$

2. $Ba(OH)_2 + CO_2 \rightarrow BaCO_3 + H_2O$

2000 mL of 1 N $Ba(OH)_2 \equiv$ 22400 mL of CO_2

5 mL of $N/50$ $Ba(OH)_2 \equiv$ 1.12 mL of CO_2

Percentage by volume in air $= \dfrac{1.12}{2500} \times 100 = 0.045.$

3. When methyl orange is used as an indicator, Na_2CO_3 is converted into NaCl.

$$\underset{106\text{ g}}{Na_2CO_3} + \underset{2\times 36.5}{2HCl} \rightarrow 2NaCl + CO_2 + H_2O$$

Equivalent weight of $Na_2CO_3 = \dfrac{106}{2} = 53.$

4. $x_1 = \dfrac{n_1}{n_1 + n_2}$ or $\dfrac{n_1 + n_2}{n_1} = \dfrac{1}{x_1}.$

$$1 + \frac{n_2}{n_1} = \frac{1}{x_1} = \frac{1}{0.5} = 2 \Rightarrow \frac{n_1}{n_2} = 1$$

or $\dfrac{w_1 \times m_2 \times 1000}{m_1 \times w_2 \times 1000} = 1 \Rightarrow \left(\dfrac{w_1 \times 1000}{m_1 \times w_2}\right)\left(\dfrac{m_2}{1000}\right) = 1.$

Molality $\times \dfrac{18}{1000} = 1 \Rightarrow$ molality$= \dfrac{1000}{18} = 55.55.$

10. 1 milliequivalent of oxalic acid $\equiv$ 0.008 g of oxygen.
20 milliequivalents of oxalic acid $\equiv$ 0.16 g of oxygen.

$\therefore$ percentage of available oxygen by weight $= \dfrac{0.16}{1.00} \times 100 = 16.$

13. 25 mL of solution $\equiv$ 8.5 mL of $N/10$ $KMnO_4$ solution.
250 mL of solution $\equiv$ 8.5 milliequivalents of $KMnO_4$ solution

$$\equiv 8.5 \times 10^{-3} \times 56 \text{ g of Fe}$$
$$= 0.476 \text{ g of Fe.}$$

19. Weight of pure $Fe_2O_3 = 1 \times \dfrac{80}{100} = 0.8$ g

$Fe_2O_3 + 6HCl = 2FeCl_3 + 3H_2O$

$FeCl_3 + H_2 \xrightarrow{\text{Zn dust}} FeCl_2 + HCl$

$Fe^{2+} + \text{oxidant} \longrightarrow Fe^{3+} + \text{reductant}$

Equivalent weight of $Fe_2O_3 = \dfrac{\text{Molecular weight}}{2} = \dfrac{160}{2} = 80$ g

Milliequivalents of Fe_2O_3 = milliequivalents of oxidant

$$\frac{0.8}{80} \times 10^3 = 16.7 \times 0.1(x) \Rightarrow x = 6$$

where x is the number of electrons involved.

22. 1 mol of $H_2S \equiv 5$ mol of H_2SO_4.

0.5 mol of $H_2SO_4 \equiv 2.5$ mol of H_2SO_4.

$$\text{Volume of } H_2SO_4 = \frac{2.5 \text{ mol}}{0.10 \text{ mol L}^{-1}} = 25.0 = 25.0 \text{ L.}$$

30. Let the volume of each electrolyte = x mL. Hence total volume = $3x$ mL

x mL of 0.25 M NaOH reacts with x mL of 0.50 M HCl to produce x mL of 0.25 M NaCl solution.

Total number of milli moles of NaCl = $0.25x + 2.75x = 3.00x$.

(Initially, the concentration of NaCl was 2.75 M)

$$\therefore \quad \text{Molarity of NaCl} = \frac{m \text{ mol}}{\text{mL}} = \frac{3.00\, x \text{ mol}}{3\, x \text{ mL}} = 1.00 \text{ M.}$$

31. Use the normality equation.

Let N_1 = normality of acid mixture.

Let volume of H_2SO_4 = x mL.

Then $(25 \times 2 + 50 \times 4 + x \times 5 \times 2)$ mL (N) = 1000 mL (N_1)

$$(50 + 200 + 10x) \text{ mL}(N) = 1000 \text{ mL } N_1 \qquad (1)$$

Secondly $[50 \text{ mL}(N_1)]_{\text{acid mixture}} = [25 \text{ mL}(N)]_{\text{alkali}}$

$$N_1 = \frac{1}{2} N \qquad (2)$$

From Equations (1) and (2),

$$(250 + 10x) \text{ mL}(N) = 1000 \text{ mL } (N/2)$$

$$\Rightarrow \quad 250 + 10x = 500 \text{ mL}$$

$$\Rightarrow \quad x = 25.0 \text{ mL.}$$

35. Milliequivalents of Ca^{2+} + milliequivalents of Mg^{2+} = milliequivalents of N_2CO_3.

$$\frac{20}{20} + \frac{12}{12} = V \times 2.$$

$\therefore \quad V = 1$ mL for 1 L of tap water.

For 1000 L of tap water,

$$V = 1000 \text{ mL} = 1 \text{ L.}$$

37. 2 L of 1.5-M $CuSO_4$ = 3 mol of $CuSO_4$.

$$\underset{2\text{ mol}}{2Al} + \underset{3\text{ mol}}{3CuSO_4} \rightarrow Al_2(SO_4)_3 + \underset{3\text{ mol}}{3\,Cu}$$

2 mol of Al ≡ 3 mol of Cu.

$$27 \text{ g} = 1 \text{ mol of Al} \equiv \frac{3}{2} \times 63.5 \text{ g of Cu} = 95.25 \text{ g.}$$

39. $N_{HCl} + N_{H_2SO_4} = 0.1.$ (1)

1 equivalent of AgCl = 1000 mL (N).

10^{-3} equivalent of AgCl = 1 mL (N)

[0.1435 g AgCl = 1×10^{-3} equivalent of AgCl]

1 mL (N) = 20 mL $\times N_{HCl} \Rightarrow N_{HCl} = 0.05.$ (2)

From Equations (1) and (2),

$$N_{H_2SO_4} = 0.05\ N.$$

Strength of $H_2SO_4 = 0.05 \times 49 = 2.45\ gL^{-1}$.

48. The sample of H_2SO_4 is 90% by volume

$\therefore \quad W_{H_2SO_4} = 900$ g in 1000 mL

Volume of solution = 1000.0 mL

Weight of solution = $1000.0 \times 1.80 = 1800$ g.

Weight of water = $1800 - 900 = 900$ g.

$$\text{Molality} = \frac{900 \times 1000}{98 \times 900} = 10.2\ \text{mol kg}^{-1}.$$

51. $N_{NaOH} = \dfrac{4\ g}{40\ \text{gram equivalent}} \times \dfrac{1}{1\ L} = 0.1\ N.$

1 milliequivalent of NaOH $\equiv$ 22.4 mL of HCl(g) at stp.

50×0.1 milliequivalent of NaOH $\equiv 22.4 \times 50 \times 0.1$ mL of HCl (g) at stp

= 112 mL of HCl (g) at stp.

52. $x \times 0.1 \times 2 - 50 \times 0.1 = (x + 50) \times 0.05 \times 2.$

$0.2x - 5 = 0.1x + 5 \Rightarrow 0.1x = 10 \Rightarrow x = 100$ mL.

56. Milliequivalents of NaOH taken = 20.

Milliequivalents of H_2SO_4 = milliequivalents of NaOH reacted

$$= \frac{10 \times 0.1}{25} \times 250 = 10.$$

Milliequivalents of NaOH reacted = $20 - 10 = 10$

1 milliequivalent NaOH $\equiv$ 0.066 g of $(NH_4)_2SO_4$.

10 milliequivalents NaOH $\equiv$ 0.66 g of $(NH_4)_2SO_4$.

$$\text{Percentage of } (NH_4)_2SO_4 = \frac{0.66}{0.70} \times 100 = 94.3.$$

71. Eq. wt. of $KBrO_3^- = \dfrac{1}{6}$ of its mol. wt. $= \dfrac{1}{6} \times 167$ g equiv.$^{-1}$

$$N_{Na_2S_2O_3} = \frac{0.1262\ g}{\frac{1}{6} \times 167\ \text{g equiv.}^{-1}} \times \frac{1}{0.045\ L} = 0.1\ N$$

For $Na_2S_2O_3$, molarity = normality, and so normality = 0.1 N

and molarity = 0.1 M

❑

11

Thermodynamics and Thermochemistry

• Type 1 •

Choose the correct option. Only one option is correct.

1. Consider an ideal gas that occupies 2.50 dm^3 at a pressure of 3.00 bar. If the gas is compressed isothermally at a constant pressure p_{ext}, so that the final volume is 0.500 dm^3, calculate the smallest possible value of p_{ext} and the work done using p_{ext}.

(a) 20 bar and 100 J (b) 15 bar and 750 J
(c) 30 bar and 150 J (d) 10 bar and 375 J

2. Calculate the work done when 1 mol of an ideal gas is compressed reversibly from 1.00 bar to 5.00 bar at a constant temperature of 300 K.

(a) −14.01 kJ (b) +18.02 kJ
(c) 4.01 kJ (d) −8.02 kJ

3. Calculate the work done when 1 mol of an ideal gas is expanded reversibly from 20.0 dm^3 to 40.0 dm^3 at a constant temperature of 300 K.

(a) 7.78 kJ (b) −1.73 kJ
(c) 11.73 kJ (d) −4.78 kJ

4. If the internal energy of an ideal gas decreases by the same amount as the work done by the system, the process is

(a) cyclic (b) isothermal (c) adiabatic (d) isolated

5. When heat is supplied to an ideal gas in an isothermal process, the

(a) gas will do positive work
(b) gas will do negative work
(c) kinetic energy of the gas will increase
(d) gas will not obey the law of conservation of energy

6. The molar heat capacity of water in equilibrium with ice at constant pressure is

(a) negative (b) zero

(c) infinity (d) 40.45 kJ K^{-1} mol^{-1}

7. Calculate the enthalpy change when 1.0 g of water is frozen at 0°C ($\Delta H_f^\circ = 1.435$ kcal mol^{-1})[3]?

(a) −1.435 cal g^{-1} (b) −80.0 cal g^{-1}

(c) 80.0 cal g^{-1} (d) −55.6 cal g^{-1}

8. The hydrogen-bond energy of water at 25°C is about

(a) 5 kcal mol^{-1} (b) 23 kcal mol^{-1}

(c) 0.1 kcal mol^{-1} (d) 100 kcal mol^{-1}

9. Which of the following sets represent the normal physical states of the elements concerned at 25°C and one bar pressure, with $\Delta H°$(formation) = 0.

(a) C(diamond), S_8(s), Na(s)

(b) C(diamond), C(graphite), Br_2(l)

(c) C(graphite), Br_2(g), P_4(white)

(d) C(graphite), Br_2(l), I_2(s)

10. 50 mL of water takes 5 minutes to evaporate from a vessel on a heater connected to an electric source which delivers 400 W. The enthalpy of vaporization of water is

(a) 40.3 kJ mol^{-1} (b) 43.2 kJ mol^{-1}

(c) 16.7 kJ mol^{-1} (d) 180.4 kJ mol^{-1}

11. The mathematical expression for the standard enthalpy of sublimation is given by

(a) $\Delta H°$(sublimation) = $\Delta H°$(fusion) – 2$\Delta H°$(vaporization)

(b) $\Delta H°$(sublimation) = $\Delta H°$(fusion) – $\Delta H°$(vaporization)

(c) $\Delta H°$(sublimation) = $\Delta H°$(fusion) + $\Delta H°$(vaporization)

(d) $\Delta H°$(sublimation) = $\Delta H°$(combustion) + $\Delta H°$(dissociation)

12. Which of the following isomeric hydrocarbons is the most stable on the basis of enthalpy of combustion?

(a) 1-Butene (b) *trans*-2-Butene

(c) 2-Methylpropene (d) *cis*-2-Butene

13. Which of the following are exothermic compounds with respect to enthalpy of formation?

(a) C_2H_2(g) (b) HI(g) (c) HBr(g) (d) I_2(s)

14. Which among the following has maximum standard enthalpy of formation?

(a) Glucose (b) Sucrose

(c) Hexane (d) Ethanol

15. In which of the following reactions is $\Delta H = \Delta U$?

(a) $H_2(g) + I_2(g) \rightarrow 2HI(g)$

(b) $KI(aq) + I_2(s) \rightarrow KI_3(aq)$

(c) $6NaOH(aq) + 3Cl_2(g) \rightarrow 5NaCl(aq) + NaClO_3(aq) + 3H_2O(l)$

(d) $N_2O_4(g) \rightarrow 2NO_2(g)$

16. Which of the following salts should cause maximum cooling when 1 mol of it is dissolved in the same volume of water?

(a) NaCl; $\Delta H^\circ = 5.35$ kJ mol^{-1}

(b) KNO_3; $\Delta H^\circ = 53.5$ kJ mol^{-1}

(c) KOH; $\Delta H^\circ = -56.0$ kJ mol^{-1}

(d) HBr; $\Delta H^\circ = -83.3$ kJ mol^{-1}

17. The standard enthalpies of formation of H^+ and OH^- ions in water are zero and -229.6 kJ mol^{-1} respectively. The standard enthalpy of formation of liquid water is -285.6 kJ mol^{-1}. Then the enthalpy of neutralization of HCl(aq) by KOH(aq) is

(a) 229.6 kJ mol^{-1} (b) -173.4 kJ mol^{-1}

(c) 56.0 kJ mol^{-1} (d) -56.0 kJ mol^{-1}

18. Given that $\Delta H_f^\circ(CO_2, g) = -393.509$ kJ mol^{-1}, $\Delta H_f^\circ(H_2O, l) = -285.830$ kJ mol^{-1}, $\Delta H_f^\circ(C_2H_5OH, l) = -277.800$ kJ mol^{-1}.

Calculate the ΔH° (combustion) of liquid ethanol. The following is the required reaction.

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$

(a) -1366.82 kJ mol^{-1} (b) -278.82 kJ mol^{-1}

(c) -2264.66 kJ mol^{-1} (d) -1155.78 kJ mol^{-1}

19. Given that the standard enthalpies of combination of C(s), $H_2(g)$ and $CH_4(g)$ are -393.5 kJ mol^{-1}, -285.8 kJ mol^{-1} and -890.4 kJ mol^{-1} respectively at 298 K. Calculate the standard enthalpy of formation of methane [$CH_4(g)$].

(a) -724.42 kJ mol^{-1} (b) -74.81 kJ mol^{-1}

(c) -114.82 kJ mol^{-1} (d) -194.62 kJ mol^{-1}

20. The molar enthalpies of combustion of isobutane and *n*-butane are -2870 kJ mol^{-1} and -2878 kJ mol^{-1} respectively at 298 K and 1 atm. Calculate ΔH° for the conversion of 1 mol of *n*-butane to 1 mol of isobutane.

(a) $-8\ \text{kJ mol}^{-1}$ (b) $+8\ \text{kJ mol}^{-1}$

(c) $-5748\ \text{kJ mol}^{-1}$ (d) $+5748\ \text{kJ mol}^{-1}$

21. Equal volumes of 1 M HCl and 1 M H_2SO_4 are neutralized by a 1 M NaOH solution, and x and y kJ/equivalent of heat are liberated respectively. Which of the following relations is correct?

(a) $x = 2y$ (b) $x = 3y$

(c) $x = 4y$ (d) $x = \frac{1}{2}y$

22. The enthalpies of hydrogenation of unsaturated hydrocarbons usually lie in the range

(a) 28–32 kcal mol^{-1} (b) 128–132 kcal mol^{-1}

(c) 224–250 kcal mol^{-1} (d) 100–130 kcal mol^{-1}

23. In which of the following thermochemical changes is $\Delta H°$ always negative?

(a) Enthalpy of solution (b) Enthalpy of hydrogenation

(c) Enthalpy of reaction (d) Enthalpy of transition

24. For which of the following processes does the enthalpy change represent the enthalpy of formation of NaOH?

(a) $Na^+(aq) + OH^-(aq) \longrightarrow NaOH(s)$

(b) $Na(s) + \frac{1}{2}O_2(g) + \frac{1}{2}H_2(g) \longrightarrow NaOH(s)$

(c) $2Na(s) + 2H_2O(l) \longrightarrow 2NaOH(aq) + H_2(g)$

(d) All of these

25. For the reaction $CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$; $\Delta H° = -67650$ cal at 25°C.

Calculate $\Delta H°$ at 100°C, given that the required molar heat capacities are as follows.

$$C_p(CO, g) = 6.97\ \text{cal °C}^{-1}$$
$$C_p(CO_2, g) = 8.97\ \text{cal °C}^{-1}$$
$$C_p(O_2, g) = 7.00\ \text{cal °C}^{-1}$$

(a) −54.6 cal (b) −67650.4 cal

(c) −67684.4 cal (d) −67762.5 cal

26. The heat of atomization of $PH_3(g)$ is 228 kcal mol^{-1} and that of $P_2H_4(g)$ is 355 kcal mol^{-1}. The energy of the P—P bond is

(a) 102 kcal mol^{-1} (b) 51 kcal mol^{-1}

(c) 26 kcal mol^{-1} (d) 204 kcal mol^{-1}

27. For a reversible process, the total change in entropy of the universe is

(a) ΔS(system) + ΔS(surroundings)

(b) ΔS(system) – ΔS(surroundings)

(c) zero

(d) negative

28. The molar enthalpy of fusion of water is 6.01 kJ mol^{-1}. The entropy change of 1 mol of water at its melting point will be

(a) 22 kJ mol^{-1} (b) 109 kJ mol^{-1}

(c) 44 kJ mol^{-1} (d) 11 kJ mol^{-1}

29. The enthalpy of fusion per gram and the corresponding molecular weights are given for five substances

	1	2	3	4	5
$\Delta H^{\circ}_{\text{fusion}}$(cal g^{-1})	100	40	80	40	60
Mol. wt. (g mol^{-1})	20	30	40	80	30

Which of the following pairs contains substances with the same molar enthalpy of fusion?

(a) 3 and 4 (b) 2 and 3

(c) 2 and 4 (d) 3 and 4

30. The enthalpy of solution of a substance is given by

(a) $\Delta H^{\circ}_{\text{soln.}} = U$ (lattice energy) + $\Delta H^{\circ}_{\text{hydration}}$

(b) $\Delta H^{\circ}_{\text{soln.}} = U$ (lattice energy) – $\Delta H^{\circ}_{\text{hydration}}$

(c) $\Delta H^{\circ}_{\text{soln.}} = -U$ (lattice energy) + $\Delta H^{\circ}_{\text{hydration}}$

(d) $\Delta H^{\circ}_{\text{soln.}} = -U$ (lattice energy) – $\Delta H^{\circ}_{\text{hydration}}$

31. Which of the following statements is incorrect?

(a) There is nothing to surround a universe.

(b) The Clausius inequality rule states that $\int_{\text{cycle}} \delta s/T \leq \Delta s$ for any process.

(c) In reversible expansion the system expands/contracts against maximum possible pressure.

(d) Gibbs free energy is not a path function.

32. Given $C_p/C_v = \gamma$. A gas goes from the initial state (p_1, V_1, T_1) to a final state (p_2, V_2, T_2) through an adiabatic process. The work done by the gas is

(a) $\dfrac{nR(T_1 - T_2)}{\gamma - 1}$ (b) $\dfrac{p_2V_2 - p_1V_1}{\gamma - 1}$

(c) $\dfrac{p_1V_1 - p_2V_2}{\gamma + 1}$ (d) $\dfrac{n\gamma R(T_2 - T_1)}{\gamma - 1}$

33. The molar heat capacity (C_m) of an ideal gas
(a) cannot be negative
(b) must be equal to either C_v or C_p
(c) must lie in the range $C_v < C_p$
(d) may have any value between $-\infty$ and $+\infty$

34. Which of the following statements is correct?
(a) For every process in an isolated system the entropy increases.
(b) The sum of two path functions is also a path function.
(c) In a relativistic endothermic process, the total mass of the system increases.
(d) ΔH is always equal to $C_p\,\Delta T$.

35. The mathematical formulation of the first law of thermodynamics, in differential form, is
(a) $\Sigma dU = 0$ (isolated system)
(b) $dU = dq - dw$ (closed system)
(c) $dU = dq - dw + \Sigma\mu_i dn_i$ (open system)
(d) all of these

36. Calculate the final temperature of a sample of a monoatomic gas that is expanded reversibly and adiabatically from 500 mL at 300 K to 2.00 L.
(a) 119 K (b) 150 K (c) 300 K (d) 20 K

37. For the reaction
$2C_6H_5CO_2H(s) + 13O_2(g) \longrightarrow 12CO_2(g) + 6H_2O(g)$
$\Delta U° = -772.7$ kJ mol^{-1} at 298 K. Calculate $\Delta H°$.
(a) +760.3 kJ mol^{-1} (b) −760.3 kJ mol^{-1}
(c) +670.3 kJ mol^{-1} (d) −790.3 kJ mol^{-1}

38. The change in entropy when the pressure of a perfect gas is changed isothermally from p_1 to p_2 is
(a) $\Delta S = nR\ln(p_1 + p_2)$ (b) $\Delta S = nR\ln(p_2/p_1)$
(c) $\Delta S = nR\ln(p_1/p_2)$ (d) $\Delta S = nR\ln\left(\dfrac{p_1 + p_2}{p_2}\right)$

39. The enthalpy of neutralization of the reaction between $CH_3COOH(aq)$ and NaOH(aq) is −13.2 kJ equiv.$^{-1}$ and that of the reaction between $H_2SO_4(aq)$ and KOH(aq) is −13.7 kJ equiv^{-1}. The enthalpy of dissociation of $CH_3COOH(aq)$ is
(a) −0.5 kJ equiv.$^{-1}$ (b) +0.5 kJ equiv.$^{-1}$

(c) -26.9 kJ equiv.$^{-1}$ (d) $+13.45$ kJ equiv.$^{-1}$

40. 80 kJ of heat is given to 36 g of water. Then the

(a) number of H^+ and OH^- ions are $1.2044 \times 10^{24} \times \frac{80}{80}$ each

(b) number of water molecules that remain in solution is

$$\frac{36}{18} \times 6.02 \times 10^{23} \times 80$$

(c) the ratio of H^+ to OH^- $\left(\frac{H^+}{OH^-}\right)$ ions $= \frac{80 \times 36}{6.02 \times 10^{23}}$

(d) numbers of H^+ and OH^- ions are $1.2044 \times 10^{24} \times 80$ each

41. The enthalpy of formation of CO_2(g) at 298 K is -394 kJ mol^{-1}. Consider the following four reactions. (Given $\Delta H^\circ_{comb}(C_6H_6, l) = -3268$ kJ mol^{-1}.)

(i) $\frac{1}{6} C_6H_6(l) + 1.25\, O_2(g) \longrightarrow CO_2(g) + \frac{1}{2} H_2O(l)$

(ii) $C(s) + \frac{1}{2} O_2(g) \longrightarrow CO(g)$

(iii) $C(s) + 2O(s) \longrightarrow CO_2(g)$

(iv) $C(s) + O_2(g) \longrightarrow CO_2(g)$

In which of these reactions will 394 kJ of heat be evolved?

(a) (i) (b) (ii) and (iv)

(c) (iv) (d) (ii), (iii) and (iv)

42. During an adiabatic process, the pressure of a gas is found to be proportional to the cube of its absolute temperature. The ratio $C_p/C_v = \gamma$ for the gas is

(a) $\frac{3}{2}$ (b) $\frac{7}{2}$ (c) $\frac{5}{3}$ (d) $\frac{9}{7}$

43. C_p is always greater than C_v for a gas. Choose the correct option.

(a) When a gas absorbs heat at constant pressure, its volume remains unchanged.

(b) No work is done by a gas at constant volume.

(c) For the same change in temperature, the internal energy of a gas changes by a smaller amount at constant volume than at constant pressure.

(d) The mass of a gas at constant pressure is greater than that at constant volume.

44. 1 gram equivalent of H_2SO_4 is treated with 112 g of KOH for complete neutralization. Which of the following statements is correct?

(a) 13.7 kcal of heat is evolved with the formation of 87 g of K_2SO_4, leaving no KOH.

(b) 27.4 kcal of heat is evolved with the formation of 87 g of K_2SO_4, leaving 4 gram equivalent of KOH.

(c) 15.7 kcal of heat is evolved with the formation of 1 gram equivalent of K_2SO_4, leaving 56 g of KOH.

(d) 13.7 kCal of heat is evolved with the formation of 87 g of K_2SO_4, leaving 1 gram equivalent of KOH.

45. 20 g of CH_4 is burnt with 150 g of O_2, producing 675 kJ of heat. Assume that the amount of oxygen required is in accordance with the equation

$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(l)$$

After the reaction, an excess of Cl_2 is added to the reaction mixture and 77 g of CCl_4 is obtained.

(a) The enthalpy of combustion of methane is –900 kJ mol^{-1} and the amount of O_2 remaining unused is 16 g.

(b) The enthalpy of combustion of methane is –900 kJ mol^{-1} and the amount of O_2 remaining unused is 48 g.

(c) The enthalpy of combustion of methane is –900 kJ mol^{-1} and the amount of O_2 remaining unused is 54 g.

(d) The enthalpy of combustion of methane is –920 kJ mol^{-1} and the amount of O_2 remaining unused is 32 g.

46. The first law of thermodynamics introduces the concepts of conservation of

(a) heat

(b) energy and equivalence of heat and work

(c) work

(d) energy and equivalence of temperature and work

47. A system is taken from state A to state B along two different paths 1 and 2. The heat absorbed and work done by the system along these paths are Q_1 and Q_2 and W_1 and W_2 respectively. Then

(a) $Q_1 = Q_2$ (b) $Q_1 + W_1 = Q_2 + W_2$

(c) $W_1 = W_2$ (d) $Q_1 - W_1 = Q_2 - W_2$

48. For a gas, $C_p/C_v = \gamma$. The molecular mass of the gas is M. Its specific heat capacity at constant pressure is

(a) $\dfrac{\gamma R}{M(\gamma - 1)}$ (b) $\dfrac{\gamma}{RM}$

(c) $\dfrac{M}{R(\gamma - 1)}$ (d) $\dfrac{\gamma RM}{\gamma + 1}$

49. Which of the following statements is incorrect when H_2SO_4 gradually goes into solution with different number of moles of water?

(a) In the reaction $H_2SO_4(l) + n_1H_2O \rightarrow H_2SO_4(n_1H_2O)$, ΔH is known as the integral enthalpy of solution.

(b) The difference between the integral enthalpies of solution of two differently specified concentrations of H_2SO_4 gives the enthalpy of dilution.

(c) The slope of a plot of the integral enthalpy of solution against the number of moles of H_2SO_4 per mole of H_2O gives the integral enthalpy of solution at infinite dilution.

(d) The slope of the plot of the integral enthalpy of solution against mol of H_2SO_4/mol of H_2O gives the differential enthalpy of solution.

50. Calculate the difference between ΔH and ΔU when 1.0 mol of grey tin (density = 5.75 g cm^{-3}) changes to white tin (density = 7.31 g cm^{-3}) at 10.0 bar (at 298 K, $\Delta H = +2.1$ kJ; atomic weight of Sn = 119.0).

(a) −8.8 J (b) −4.4 J (c) −2.2 J (d) +4.4 J

51. If water at 0°C, kept in a container with an open top, is placed in a large evacuated chamber,

(a) all the water will freeze

(b) all the water will vaporize

(c) part of the water will vaporize and the rest will freeze

(d) ice, water and water vapour will be formed and reach equilibrium at the triple point

52. The standard enthalpy of formation of gaseous H_2O at 298 K is −241.82 kJ mol^{-1}. Calculate $\Delta H°$ at 373 K given the following values of the molar heat capacities at constant pressure.

Molar heat capacity of $H_2(g)$ = 33.58 jK^{-1} mol^{-1}

Molar heat capacity of $H_2(g)$ = 28.84 jK^{-1} mol^{-1}

Molar heat capacity of $O_2(g)$ = 29.37 jK^{-1} mol^{-1}

Assume that the heat capacities are independent of temperature.

(a) −242.6 kJ mol^{-1} (b) −485.2 kJ mol^{-1}

(c) −121.3 kJ mol^{-1} (d) −286.4 kJ mol^{-1}

53. The enthalpy of neutralization of oxalic acid ($H_2C_2O_4$) by a strong base is −25.4 kcal mol^{-1}. The enthalpy of neutralization of the reaction between a strong acid and strong base is −13.7 kcal equiv^{-1}. The enthalpy of dissociation of $H_2C_2O_4 \rightleftharpoons 2H^+ + C_2O_4^{2-}$ is

(a) 1.0 kcal mol^{-1} (b) 2.0 kcal mol^{-1}

(c) 18.55 kcal mol^{-1} (d) 11.7 kcal mol^{-1}

54. The temperature of 25 mL of an HCl solution increases by 10°C when 25 mL of NaOH is added to it. What will be the increase in the temperature of 50 mL of this HCl solution when 50 mL of the same solution of NaOH is added to it?

(a) 50°C (b) 25°C

(c) 12.5°C (d) 35°C

55. Which of the following statements is incorrect?

(a) The carnot cycle is not specifically meant for gases and can always be applied to mechanical or electromagnetic systems so long as the thermodynamic processes have proper analogs.

(b) The Carnot cycle can be carried out for nonthermodynamic systems such as those involving paramagnetic substances and surface films.

(c) An ideal Carnot cycle has 100% efficiency.

(d) The efficiency of a Carnot cycle is independent of the working substance employed because all reversible engines are necessarily less efficient than the Carnot heat engine.

56. Which of the following has a positive enthalpy of formation?

(a) $NH_3(g)$ (b) $COCl_2(l)$

(c) $S_2Cl_2(s)$ (d) HN_3

57. Which of the following has the greatest enthalpy of combustion per gram?

(a) $H_2(g)$ (b) $CH_3OH(l)$

(c) $CH_3CH_2OH(l)$ (d) $C_2H_6(g)$

58. Which of the following statements is incorrect?

(a) The specific heat capacity of a substance is greater in the solid state than in the liquid state.

(b) The specific heat capacity of a substance is greater in the liquid state than in the solid state.

(c) The latent heat of vaporization of a substance is greater than that of fusion.

(d) The internal energy of an ideal gas is a function of its temperature.

59. If we consider U as a function of S and V, then

(a) $dU = \left(\frac{\partial U}{\partial S}\right)_v dS + \left(\frac{\partial U}{\partial V}\right)_s dV$ (b) $\left(\frac{\partial U}{\partial S}\right)_v = T$

(c) $\left(\frac{\partial U}{\partial V}\right)_s = -p$ (d) all of these

60. Which of the following is an inexact differential?

(a) dq (b) $dq \times \frac{1}{T}$

(c) C_p (d) H

61. In which of the following processes does the entropy decrease?

(a) The dissolving of sodium chloride in water

(b) The evaporation of water

(c) The conversion of CO_2(g) into dry ice

(d) When a dozen marbles are taken out of a small bag and dropped on the ground

62. A gas obeys the equation of state $pV = nRT + nbp$ where b is a constant. If n moles of the gas expand from V_1 to V_2 reversibly at a constant temperature T, the work done is given by

(a) $-nRT\ \ln[(V_2 - nb)/(V_1 - nb)]$

(b) $nRT\ \ln[(V_2 - nb)/V_2 - nb)]$

(c) zero

(d) $-nRT\ \ln[(V_1 - nb)/(V_2 - nb)]$

63. Calculate the enthalpy change when 50 mL of 0.01 M $Ca(OH)_2$ reacts with 25 mL of 0.01 M HCl. Given that $\Delta H^{\circ}_{\text{neut}}$ of a strong acid and strong base is 140 kcal equivalent.

(a) 14.0 cal (b) 35 cal

(c) 10.0 cal (d) 7.5 cal

64. The enthalpy of neutralization of a strong acid by a strong base is -57.32 kJ mol^{-1}. The enthalpy of formation of water is -285.84 kJ mol^{-1}. The enthalpy of formation of the hydroxyl ion is

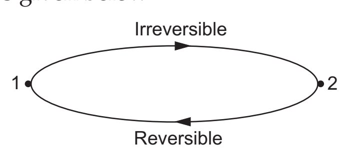
(a) $+228.52$ kJ mol^{-1} (b) -114.26 kJ mol^{-1}

(c) -228.52 kJ mol^{-1} (d) $+114.26$ kJ mol^{-1}

65. A current of 10 A from a 12-V battery is passed through a heating element in a calorimeter for 300 s. If the temperature of the calorimeter rises by 5.5 K, the calorimeter constant is

(a) 4.5 kJ K^{-1} (b) 45.0 kJ K^{-1} (c) 450 kJ K^{-1} (d) 6.5 kJ K^{-1}

66. In a cyclic process given below



(a) $\Delta S = 0 > \int_1^2 \frac{dq_{rev}}{T}$ (b) $\Delta S = 0 > \int_1^2 \frac{dq_{rev}}{T} + \int_1^2 \frac{dq_{irr}}{T}$

(c) $\Delta S = 0 > \int_1^2 \frac{dq_{irr}}{T} + \int_2^1 \frac{dq_{rev}}{T}$ (d) $\Delta S = 0 > \int_2^1 \frac{dq_{irr}}{T} + \int_2^1 \frac{dq_{rev}}{T}$

67. The total entropy change for irreversible process is given by

(a) $\Delta S_{\text{total}} = \Delta S_{\text{sys}} + \Delta S_{\text{surr}} = 0$

(b) $\Delta S_{\text{total}} = \Delta S_{\text{sys}} + \Delta S_{\text{surr}} = nR\ln V_2/V_1$

(c) $\Delta S_{\text{total}} = \Delta S_{\text{sys}} + \Delta S_{\text{surr}} = nR\ln V_2/V_1 + C_v dT$

(d) $\Delta S_{\text{total}} = \Delta S_{\text{sys}} + \Delta S_{\text{surr}} = nR\ln V_1/V_2$

68. Which of the following conditions for entropy is incorrect?

(a) The state of equilibrium corresponds to maximum entropy of the universe

(b) The system maintained at constant entropy and constant volume will attain the equilibrium at a state of minimum energy

(c) The necessary condition $(dS)_{U,V} < 0$, $(dU)_{S,V} > 0$ sufficient condition $dS > 0$, $dU > 0$.

(d) The necessary condition $(dS)_{U,V} > 0 (dU)_{S,V} < 0$ sufficient condition $dS < 0$, $dU < 0$.

69. In a reversible adiabatic change ΔS is

(a) infinity
(b) zero
(c) equal to $C_v dT$
(d) equal to $nR\ln V_2/V_1$

70. In an adiabatic irreversible expansion, the external pressure is constant and the work of expansion is given by

(a) $(-W_{irr}) = P_{ext}\left(\frac{nRT_2}{p_2} - \frac{nRT_1}{p_1}\right)$
(b) $(-W_{irr}) = P_{ext}\,(nRT_2 - nRT_1)$
(c) $(-W_{irr}) = P_{ext}\,(nRT_2 + nRT_1)$
(d) none of these

71. When ideal gases are mixed together, the molar entropy of mixing is given by

(a) $\Delta\overline{S}_{mix} = -R\sum_{j=1}^{N} y_j \ln y_j$
(b) $\Delta\overline{S}_{mix} = -nR\sum_{j=1}^{N} y_j \ln y_j$
(c) $\Delta\overline{S}_{mix} = +R\sum_{j=1}^{N} y_j \ln y_j$
(d) $\Delta\overline{S}_{mix} = -nRT\sum_{j=1}^{N} y_j \ln y_j$

72. The direction of a spontaneous process for a system at constant pressure and temperature is given by

(a) $d(U - TS + PV) \geq 0$
(b) $d(U - TS + PV) \leq 0$
(c) $d(U - TP + VS) \leq 0$
(d) $d(U - TS + Vn) \leq 0$

• Type 2 •

Choose the correct options. More than one option is correct.

73. Which of the following expression represents Gibbs–Helmholtz equation?

(a) $\Delta G° = \Delta H° + T\left[\frac{\partial(\Delta G°)}{\partial T}\right]_p$ (b) $\left[\frac{\partial(\Delta G°)}{\partial T}\right]_p = -\frac{\Delta H°}{T^2}$

(c) $\left[\frac{\partial(\Delta G°/T)}{\partial(1/T)}\right]_p = \Delta H°$ (d) $\left[\frac{\partial(\Delta G°/T)}{\partial T}\right]_p = -\Delta H°$

74. In an isothermal irreversible expansion of an ideal gas

(a) $\Delta U = 0$ (b) $-wq = nRT[1 - P_2/P_1]$

(c) $\Delta H \neq 0$ (d) all of these

75. The differential form of thermodynamic energies U, H and G can be represented by

(a) $dU = Tds - pdv$ (b) $dH = Tds + Vdp$

(c) $dG = -SdT + Vdp$ (d) none of these

76. Which of the following mathematical relations are correct for an ideal gas?

(a) $\left(\frac{\partial H}{\partial V}\right)_T = 0$ (b) $\left(\frac{\partial H}{\partial p}\right)_T = 0$

(c) $C_p - C_V > R$ (d) $\left(\frac{\partial C_V}{\partial V}\right)_T = 0$

77. Which of these mathematical expressions is a perfect differential?

(a) $\int_1^2 dU = \Delta U$ (b) $\int_1^2 \delta W = \Delta W$

(c) $\int_1^2 \delta q = \Delta q$ (d) $dU = \delta q + \delta W$

78. An adiabatic process is one in which

(a) all energy is transferred as heat

(b) no energy is transferred as heat

(c) the temperature of a gas decreases in a reversible adiabatic expansion

(d) $dU \neq dW$

79. When the gas is ideal and the process is isothermal

(a) $p_1V_1 = p_2V_2$ (b) $U_1 = U_2$ (c) $H_1 \neq H_2$ (d) $W = 0$

80. Which of the following statements are correct?

(a) The work done by the system on the surroundings is negative.

(b) The work done on the system by the surroundings is positive.

(c) The heat absorbed by the system from the surroundings is positive.

(d) The heat absorbed by the surroundings from the system is negative.

81. Which of the following is a path function as well as an extensive property?

(a) Temperature (b) Internal energy

(c) Molar heat capacity (d) Heat capacity

82. For ideal diatomic gases,

(a) $C_p = (7/2)R$ (b) $C_p = (3/2)R$

(c) $C_V = (5/2)R$ (d) $C_V = (3/2)R$

83. When a solid melts there will be

(a) an increase in enthalpy

(b) a decrease in free energy

(c) no change in enthalpy

(d) a decrease in internal energy

84. Which of the following are thermodynamically stable?

(a) C(diamond) (b) C(graphite)

(c) P_4(white) (d) P_4(red)

85. Which of the following are endothermic compounds?

(a) $N_2O_4(g)$ (b) $NO_2(g)$

(c) $N_2O_4(l)$ (d) $N_2H_4(l)$

86. The standard molar enthalpy of CO_2 is equal to

(a) the standard molar enthalpy of combustion of gaseous carbon

(b) the standard molar enthalpy of combustion of carbon (graphite)

(c) the sum of the standard molar enthalpies of formation of CO and O_2

(d) -394 kJ mol^{-1}

87. Which of the following statements are correct?

(a) The entropy of an isolated system increases in an irreversible process.

(b) The entropy of an isolated system remains unchanged in a reversible process.

(c) Entropy can never decrease.
(d) ΔS(system) as well as ΔS(surroundings) are negative quantities.

88. Which of the following statements are correct?
(a) When $\Delta G = 0$, the system is at equilibrium.
(b) When $\Delta G < 0$, the process will be spontaneous.
(c) When ΔG is negative, the process is said to be exergonic.
(d) When ΔG is positive, the process is said to be endergonic.

89. Which of the following relations are correct?
(a) $\Delta G = \Delta H - T\Delta S$
(b) $\Delta G = \Delta H + T\left[\frac{\partial(\Delta G)}{\partial T}\right]_p$
(c) $\Delta G = \Delta H + T\Delta S$
(d) $\Delta G = \Delta H + \Delta nRT$

90. In the following table, which of the options are correct?

	ΔH	ΔS	Nature of reaction
(a)	(−)	(+)	Spontaneous at all temperatures
(b)	(+)	(−)	Nonspontaneous regardless of temperature
(c)	(+)	(+)	Spontaneous only at high temperature
(d)	(−)	(−)	Spontaneous only at low temperature

Answers

1. b	**2.** c	**3.** b	**4.** c	**5.** a
6. c	**7.** b	**8.** a	**9.** d	**10.** b
11. c	**12.** c	**13.** c	**14.** b	**15.** a
16. b	**17.** d	**18.** a	**19.** b	**20.** a
21. d	**22.** a	**23.** b	**24.** b	**25.** d
26. b	**27.** c	**28.** a	**29.** d	**30.** a
31. b	**32.** a	**33.** d	**34.** c	**35.** d
36. a	**37.** b	**38.** c	**39.** b	**40.** a
41. c	**42.** a	**43.** b	**44.** d	**45.** c
46. b	**47.** d	**48.** a	**49.** c	**50.** b
51. c	**52.** a	**53.** b	**54.** b	**55.** d
56. d	**57.** a	**58.** b	**59.** d	**60.** a
61. c	**62.** a	**63.** b	**64.** c	**65.** d
66. c	**67.** b	**68.** c	**69.** b	**70.** a
71. a	**72.** b	**73.** a, c	**74.** a, b	**75.** a, b, c

76. a, b, d	**77.** a, d	**78.** b, c	**79.** a, b	**80.** a, b, c, d
81. b, d	**82.** a, c	**83.** a, b	**84.** b, c	**85.** a, b, d
86. b, d	**87.** a, b, c	**88.** a, b, c, d	**89.** a, b	**90.** a, b, c, d

Hints to More Difficult Problems

1. For a compression to occur, p_{ext} must be at least as large as the final pressure of the gas. The final pressure of the gas is

$$P_{\text{f}} = \frac{p_{\text{i}}V_{\text{i}}}{V_{\text{f}}} = \frac{(3.0 \text{ bar})(2.50 \text{ dm}^3)}{0.50 \text{ dm}^3} = 15.0 \text{ bar}$$

This is the smallest possible value of p_{ext} that can be applied to compress the gas isothermally from 2.50 dm^3 to 0.5 dm^3. The work done involving the value of p_{ext} is

$$\begin{aligned} W &= -p_{\text{ext}}\Delta V = -(15 \text{ bar})(-0.5 \text{ dm}^3) = 7.5 \text{ dm}^3 \text{ bar} \\ &= (7.5 \text{ dm}^3 \text{ bar})(10^{-3} \text{ m}^3\text{dm}^{-3})(10^5) \text{ Pa bar}^{-1} \\ &= 750 \text{ Pa} \cdot \text{m}^3 = 750 \text{ J}. \end{aligned}$$

6. $C_{p,m} \; \underset{T \to 0}{Lt} \left(\frac{\partial H}{\partial T}\right)_{\text{p}} = \propto$

10. Work done in 1 s = 400 J.

Work done in 300 s = 120,000 J = 120 kJ.

$$\Delta H^\circ_{\text{vap}} = \frac{120 \text{ kJ}}{{}^{50}\!/_{18} \text{ mol}} \text{ (assume density of water = 1.00 g cm}^{-3}\text{)}$$

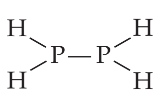
$$= 43.2 \text{ kJ mol}^{-1}.$$

15. $\Delta n = 0$, and hence $\Delta H = \Delta U$.

20. $\Delta H^\circ_{\text{iso}} = -2878 - (-2870) = 8 \text{ kJ mol}^{-1}$.

26. Bond dissociation energy of PH_3(g) = 228 kcal mol^{-1}.

P—H bond energy $= \frac{228}{3} = 76 \text{ kcal mol}^{-1}$



Bond energy of 4(P – H) + (P – P) = 355 kcal mol^{-1}

or, $4 \times 76 + (\text{P} - \text{P}) = 355 \text{ kcal mol}^{-1}$

$\therefore$ P – P bond energy = 51 kcal mol^{-1}

33. By definition, $C_m = \frac{1}{n}\frac{\Delta Q}{\Delta T}$.

Set ΔQ and ΔT to get the result.

36. Use the equation $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{2/3}$.

39. $\Delta H^\circ_{\text{neut}}$ (obs) $= \Delta H^\circ_{\text{neut}}$ (actual) $+ \Delta H^\circ_{\text{diss}}$

42. $T^\gamma p^{1-\gamma} =$ constant or $p \propto T^{(\gamma/\gamma-1)}$. Given, $p \propto T^3$.

$$\therefore \quad \frac{\gamma}{\gamma - 1} = 3 \Rightarrow \gamma = \frac{3}{2}.$$

44. Use the principle of enthalpy of neutralization.

48. Specific heat capacity $= \frac{\text{molar heat capacity}}{\text{molar mass}}$.

50. $V_{\text{grey tin}} = \frac{119.0}{5.75} = 20.696.$

$V_{\text{white tin}} = \frac{119.0}{7.31} = 16.279.$

$$p\Delta V = (10 \times 10^5 \text{ Pa})(-20.696 + 16.279) \times 10^{-6} \text{ m}^3.$$
$$= -4.4 \text{ kJ}$$

52. The reaction is $H_2(g) + \frac{1}{2} O_2(g) \longrightarrow H_2O(g)$

$$\Delta C^\circ_p = C^\circ_{p,m}(H_2O, g) - \left\{C^\circ_{p,m}(H_2, g) + \frac{1}{2} C^\circ_{p,m}(O_2, g)\right\}$$
$$= 33.58 - \left\{28.84 + \frac{1}{2}(29.37)\right\}$$
$$= -9.94 \text{ JK}^{-1} \text{ mol}^{-1}.$$

Using Kirchhoff's equation,

$$\Delta H^0(373 \text{ K}) = \Delta H^\circ(298 \text{ K}) + (T_2 - T_1)\Delta C^\circ_p$$
$$= -241.82 + (373 - 298) \times (-9.94)$$
$$= -242.6 \text{ kJ mol}^{-1}$$

53. $\Delta H^\circ_{\text{neut}}$(obs) $= \Delta H^\circ_{(\text{neut})}$ (actual) $+ \Delta H^\circ_{\text{diss}}$.
Since the acid is diprotic,

$$\therefore \quad \Delta H^\circ_{\text{diss}} = -25.4 - (-13.7 \times 2)$$
$$= 27.4 - 25.4$$
$$= 2.0 \text{ kcal mol}^{-1}.$$

58. Lower molar mass.

59. Differentiate $U = f(S, V)$ and compare with the equation $dU = TdS - pdV$.

60. q is not a state function.

63. Number of milliequivalent of $Ca(OH)_2 = 50 \times 2 \times 0.01 = 1.00$.

Number of milliequivalents of $HCl = 25 \times 0.01 = 0.25$.

0.25 milliequivalents of HCl will be neutralized by 0.25 milliequivalents of $Ca(OH)_2$.

1 equivalent corresponds to 140.0 kcal

Therefore, 0.25×10^{-3} equivalent corresponds to $140.0 \times 0.25 \times 10^{-3}$ kcal $= 35$ cal.

64. (a) $H^+(aq) + OH^-(aq) \longrightarrow H_2O(l),\ \Delta H^\circ = -57.32\ \text{kJ mol}^{-1}$

(b) $H_2(g) + \frac{1}{2}O_2(g) \longrightarrow H_2O(l),\ \Delta H^\circ = -285.84\ \text{kJ mol}^{-1}$

$$(a) - (b) = \underset{\substack{\downarrow \\ \text{zero}}}{H^+(aq)} + \underset{\substack{\downarrow \\ x}}{OH^-(aq)} \longrightarrow \underset{\substack{\downarrow \\ \text{zero}}}{H_2(g)} + \frac{1}{2}\underset{\substack{\downarrow \\ \text{zero}}}{O_2(g)}\ \ \Delta H^\circ = +228.52\ \text{kJ mol}^{-1}$$

$$\Delta H^\circ = \Sigma\Delta H_p^\circ - \Sigma\Delta H_R^\circ$$

$$228.52 = (0 + 0) - (x + 0)$$

$$\therefore\ \ x = -228.52\ \text{kJ mol}^{-1}.$$

69. For adiabatic changes $q = 0$

77. Internal enegry (U) is a state function.

80. Use the law of acquisition.

❑

12

Chemical Equilibrium

• *Type 1* •

Choose the correct option. Only one option is correct.

1. Which of the following is true at chemical equilibrium?

(a) $(\Delta G)_{T,p}$ is minimum and $(\Delta S)_{U,V}$ is also minimum.

(b) $(\Delta G)_{T,V}$ is minimum and $(\Delta S)_{U,V}$ is maximum.

(c) $(\Delta G)_{T,V}$ is maximum and $(\Delta S)_{U,V}$ is zero.

(d) $(\Delta G)_{T,p}$ is zero and $(\Delta S)_{U,V}$ is also zero.

2. In the reaction, $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$,

(a) $K_p = K_x(RT)^2$

(b) $K_p = \dfrac{K_N}{(RT)^2}$

(c) $K_c = \dfrac{K_p}{(RT)^{-2}}$

(d) $K_p = \dfrac{K_x}{(RT)^2}$

3. The equilibrium of the reaction $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ will shift to the product side when

(a) $K_p > 1$

(b) $Q < K_p$

(c) $Q = K_p$

(d) $Q < 2K_p$

4. Which of the following expressions is correct?

(a) $K_p = K_c\left(\dfrac{RT}{\Sigma n}\right)^{\Delta n}$

(b) $K_p = K_x\left(\dfrac{p}{\Sigma n}\right)^{\Delta n}$

(c) $K_p = K_N\left(\dfrac{p}{\Sigma n}\right)^{\Delta n - 1}$

(d) $K_p = K_c\left(\dfrac{p}{\Sigma n}\right)^{-\Delta n + 1}$

5. It is found that the equilibrium constant increases by a factor of four when the temperature is increased from 25°C to 40°C. The value of $\Delta H°$ is

(a) 25.46 kJ mol^{-1} (b) 171.67 kJ mol^{-1}

(c) 89.43 kJ mol^{-1} (d) 71.67 kJ mol^{-1}

6. In which of the following systems will the equilibrium be shifted to the right if the volume is increased at constant temperature?

(a) $A_2(g) + B_2(g) \rightleftharpoons 2AB(g)$ (b) $A_2(g) + 3O_2(g) \rightleftharpoons 2AO_3$

(c) $A_2(g) \rightleftharpoons 2A(g)$ (d) $A_2(g) + 4B_2(g) \rightleftharpoons 2AB_4(g)$

7. The equilibrium constants for the following reactions at 1400 K are given.

$2H_2O(g) \rightleftharpoons 2H_2(g) + O_2(g);\ K_1 = 2.1 \times 10^{-13}$

$2CO_2(g) \rightleftharpoons 2CO(g) + (g);\ K_2 = 1.4 \times 10^{-12}$

Then the equilibrium constant K for the reaction

$H_2(g) + CO_2(g) \rightleftharpoons CO(g) + H_2O(g)$

is

(a) 2.04 (b) 20.5

(c) 2.6 (d) 8.4

8. The equilibrium constant for the reaction

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

is 4.0 at 1000 K. When equimolar mixtures of CO and H_2O are heated to 1000 K, the percentage of CO_2 formed at equilibrium is

(a) 67 (b) 33

(c) 50 (d) 78

9. K_c for the reaction $A(g) + B(g) \rightleftharpoons 2C(g)$ is 3.0 at 400 K. In an experiment a mol of A is mixed with 3 mol of B in a 1-L vessel. At equilibrium 3 mol of C is formed. The value of a will be

(a) 4.5 mol (b) 9.5 mol

(c) 2.5 mol (d) 3.5 mol

10. For the reaction $AB(g) \rightleftharpoons A(g) + B(g)$, AB is 33% dissociated at a total pressure of p. Then

(a) $p = K_p$ (b) $p = 4K_p$

(c) $p = 3K_p$ (d) $p = 8K_p$

11. For the equilibrium of the reaction $AB(g) \rightleftharpoons A(g) + B(g)$, the numerical value of K_p is four times that of the total pressure. Calculate the number of moles of A formed.

(a) 0.1 (b) 0.09 (c) 0.05 (d) 0.9

12. For the reaction $A(g) \rightleftharpoons B(g) + C(g)$,

(a) $K_p = \alpha^3 p$ (b) $K_p = \alpha^2(K_p + p + 1)$

(c) $K_p = \alpha^2(K_p + p)$ (d) $K_p = \alpha^2\left(\frac{K_p + p}{p}\right)$

13. Consider the reactions

(i) $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g); K_1$

(ii) $CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g); K_2$

(iii) $CH_4(g) + 2H_2O(g) \rightleftharpoons CO_2(g) + 4H_2(g); K_3$

Which of the following is correct?

(a) $K_3 = K_1/K_2$ (b) $K_3 = K_1^2/K_2{}^3$

(c) $K_3 = K_1K_2$ (d) $K_3 = K_1\sqrt{K_2}$

14. For the equilibrium of the reaction

$$HgO(s) \rightleftharpoons Hg(g) + \frac{1}{2}O_2(g)$$

(a) $K_p = \frac{2}{3^{3/2}}p^{3/2}$ (b) $K_p = \frac{2}{3^{1/2}}p^{1/2}$

(c) $K_p = \frac{1}{3^{2/3}}p^{3/2}$ (d) $K_p = \frac{1}{3^{2/3}}p$

15. The total pressure observed at equilibrium in the dissociation of solid ammonium carbamate at a certain temperature is 2.0 atm. The equilibrium constant K_p is

(a) 4.185 (b) 1.185 (c) 2.276 (d) 1.072

16. XY_2 dissociates as $XY_2(g) \rightleftharpoons XY(g) + Y(g)$. When the initial pressure of XY_2 is 600 mm of Hg, the total pressure developed is 800 mm of Hg. K_p for the reaction is

(a) 200 (b) 50 (c) 100 (d) 150

17. For the reaction

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

the equilibrium constant K_p depends on the

(a) total pressure (b) catalyst used

(c) amount of H_2 and I_2 (d) temperature

18. When pressure is applied to the equilibrium system ice(s) $\rightleftharpoons H_2O(l)$, which of the following will happen?

(a) More ice will be formed.

(b) Water will evaporate.

(c) More water will be formed.

(d) Equilibrium will not be reached.

19. In which of the following reactions is the standard reaction entropy positive and does $\Delta G°$ decrease sharply with increasing temperature?

(a) $M(s) + \frac{1}{2}O_2(g) \rightarrow MO(s)$ (b) $\frac{1}{2}C(s) + \frac{1}{2}O_2(g) \rightarrow \frac{1}{2}CO_2(g)$

(c) $C(s) + \frac{1}{2}O_2(g) \rightarrow CO(g)$ (d) $CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$

20. The standard free energy of formation of $NH_3(g)$ is -16.48 kJ mol^{-1}. The value of the equilibrium constant ($R = 8.314$ JK^{-1} mol^{-1}) is

(a) 6×10^5 (b) 3×10^5

(c) 1×10^5 (d) 9×10^5

21. Which of the following is correct for the equilibrium of the reaction

$$C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g)$$

(a) $p_{H_2} \propto p_{H_2O}$ (b) $p_{H_2} \propto \sqrt{p_{H_2O}}$

(c) $p_{H_2} \propto p_{H_2O}^2$ (d) $p_{H_2} \propto \dfrac{p_{H_2O}^2}{p_{CO}}$

22. The reactions

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g) \text{ and } COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$$

are simultaneously in equilibrium in an equilibrium box at constant volume. A few moles of CO(g) are later introduced into the vessel. After some time, the new equilibrium concentration of

(a) PCl_5 will remain unchanged

(b) Cl_2 will be greater

(c) PCl_5 will become less

(d) PCl_5 will become greater

23. At constant pressure, upon the addition of helium at the equilibrium point in the reaction $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$, the degree of dissociation of

(a) PCl_5 will decrease (b) PCl_5 will increase

(c) PCl_3 will increase (d) Cl_2 will increase

24. At constant pressure, the presence of argon at the equilibrium of $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ will

(a) reduce the formation of NH_3

(b) increase the formation of NH_3

(c) reduce the formation of H_2

(d) increase the formation of both N_2 and H_2

25. At the equilibrium of the reaction $N_2O_4(g) \rightleftharpoons 2NO_2(g)$, the observed molar mass of N_2O_4 is 77.70 g. The percentage dissociation of N_2O_4 is

(a) 28.4 (b) 46.7

(c) 22.4 (d) 18.4

26. The value of K_p for the equilibrium of the reaction $N_2O_4(g) \rightleftharpoons 2NO_2(g)$ is 2. Calculate the percentage dissociation of N_2O_4 at a pressure of 0.5 atm.

(a) 71 (b) 50

(c) 25 (d) 88

27. 1 mol of $N_2O_4(g)$ at 300 K is kept in a closed container under 1 atm. It is heated to 600 K, upon which 20% by mass of $N_2O_4(g)$ decomposes to $NO_2(g)$. The resultant pressure is

(a) 1.2 atm (b) 2.4 atm
(c) 2.0 atm (d) 1.0 atm

28. A reaction at equilibrium involving 2 mol each of PCl_5, PCl_3 and Cl_2 is maintained at 250°C and a total pressure of 3 atm. The value of K_p is

(a) 2 (b) 3
(c) 4 (d) 1

29. The equilibrium constant for the reaction

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

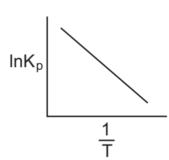
is 3.0 at 723 K and 1 atm pressure. The initial amount of water gas is 60 g and that of steam 90 g. At equilibrium the number of moles of CO_2 is

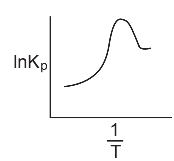
(a) 4.5 (b) 1.5
(c) 2.5 (d) 3.5

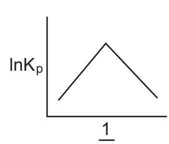
30. At the equilibrium of the reaction $2X(g) + Y(g) \rightleftharpoons X_2Y(g)$, the number of moles of X_2Y at equilibrium is affected by the

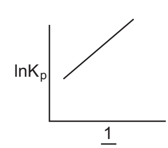
(a) temperature and pressure
(b) temperature only
(c) pressure only
(d) temperature, pressure and catalyst used

31. Which of the following graphs represents an exothermic reaction?

(a)


(b)


(c)


(d)


32. K_c for the equilibrium of

$$CH_3CO_2H(l) + C_2H_5OH(l) \rightleftharpoons CH_3CO_2C_2H_5(l) + H_2O(l)$$

is 4. How much ester is formed if 2 mol of the acid and 1 mol of the alcohol are taken initially to bring the reaction to equilibrium?

(a) 3.15 (b) 0.85
(c) 1.25 (d) 0.25

33. Consider the dissociation $N_2O_4(g) \rightleftharpoons 2NO_2(g)$. If we start with n_0 moles of $N_2O_4(g)$, then the extent of the reaction is given by

(a) $\dfrac{\zeta_{eq}}{n_0} = \left(\dfrac{K_p}{K_p + 4p}\right)$ (b) $\dfrac{\zeta_{eq}}{n_0} = \left(\dfrac{K_p + 4p}{K_p}\right)^{1/2}$

(c) $\dfrac{\zeta_{eq}}{n_0} = \left(\dfrac{4K_p}{p}\right)^{1/2}$ (d) $\dfrac{\zeta_{eq}}{n_0} = \left(\dfrac{K_p}{K_p + 4p}\right)^{1/2}$

34. The equilibrium constant for the decomposition of water

$$[H_2O(g) \longrightarrow H_2(g) + \frac{1}{2}O_2(g)]$$

is given by

(a) $K = \dfrac{\alpha^3 p^{1/2}}{(1+\alpha)(2-\alpha)^{1/2}}$ (b) $K = \dfrac{\alpha^{3/2} p^{1/2}}{(1-\alpha)(2+\alpha)^{1/2}}$

(c) $K = \dfrac{\alpha^3 p^{1/2}}{\sqrt{2}}$ (d) $K = \dfrac{\alpha^3 p^{3/2}}{(1-\alpha)(2+\alpha)^{1/2}}$

35. In the equilibrium $H_2O(g) \rightleftharpoons H_2(g) + \frac{1}{2}O_2(g)$, the extent of dissociation of water when $p = 1$ atm and $K = 2.08 \times 10^{-3}$ is approximately

(a) 2% (b) 0.2% (c) 20% (d) 1%

36. In the van't Hoff equation

$$\frac{d \ln K}{dT} = \frac{\Delta H°}{RT^2}$$

(a) when $\dfrac{d \ln K}{dT} < 0$, the reaction is exothermic

(b) when $\dfrac{d\ln K}{dT} < 0$, the reaction is endothermic

(c) the slope of the graph is positive throughout

(d) the slope of the graph increases and then decreases

37. When $-\ln K$ is plotted against $\dfrac{1}{T}$ using the van't Hoff equation, a straight line is expected with a slope equal to

(a) $\Delta H°/RT$ (b) $-\Delta H°/R$

(c) $\Delta H°/R$ (d) $R/\Delta H°$

38. In a gas-phase reaction $2A + B \rightleftharpoons 3C + 2D$ it was found that when 1.00 mol of A, 2.00 mol of B, and 1.00 mol of D were mixed and allowed to come to equilibrium at 25°C, the resulting mixture contained 0.90 mol of C at a total pressure of 1.00 bar. The value of K_p for the reaction is

(a) 6.86 (b) 4.86

(c) 68.6 (d) 10.86

39. In the expression $-\frac{\Delta G}{T} = -\frac{\Delta H}{T} + \Delta S$

(a) when the reaction is exothermic, $-\frac{\Delta H}{T}$ corresponds to a positive change of entropy of the surroundings, and favours the formation of the products

(b) when the reaction is endothermic, $-\frac{\Delta H}{T}$ corresponds to a negative change of entropy of the surroundings, and favours the formation of the products

(c) when the reaction is exothermic, $-\frac{\Delta H}{T}$ corresponds to a negative change of entropy of the surroundings, and favours the formation of the reactants

(d) when the reaction is indothermic, $-\frac{\Delta H}{T}$ corresponds to a positive change of entropy of the surroundings, and favours the formation of the reactants

40. Predict the effect of a tenfold increase in pressure on the equilibrium composition of the reaction $3N_2(g) + H_2(g) \rightleftharpoons 2NH_3(g)$.

(a) A thousandfold increase in K_x

(b) A hundredfold increase in K_x

(c) A tenfold decrease in K_x

(d) A hundredfold decrease in K_x

41. On the basis of $\Delta G°$, predict which of the following oxides can be reduced to the corresponding metal easily even in the absence of carbon.

(a) Ag_2O (b) CuO

(c) Al_2O_3 (d) Fe_2O_3

42. At constant pressure, the presence of inert gases

(a) reduces the dissociation of PCl_5

(b) increases the dissociation of PCl_5

(c) does not affect the degree of dissociation of PCl_5

(d) steps up the formation of PCl_5

43. At constant pressure, the addition of argon

(a) reduces the formation of ammonia from nitrogen and hydrogen

(b) increases the formation of ammonia from nitrogen and hydrogen

(c) does not affect the equilibrium of the reaction in which ammonia is formed from nitrogen and hydrogen

(d) reduces the dissociation of ammonia

44. Consider the reactions

(i) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

(ii) $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

The addition of an inert gas at constant volume

(a) will increase the dissociation of PCl_5 as well as N_2O_4

(b) will reduce the dissociation of PCl_5 as well as N_2O_4

(c) will increase the dissociation of PCl_5 and step up the formation of NO_2

(d) will not disturb the equilibrium of the reactions

45. What is the effect of the reduction of the volume of the system for the equilibrium $2C(s) + O_2(g) \rightleftharpoons 2CO(g)$?

(a) The equilibrium will be shifted to the left by the increased pressure caused by the reduction in volume.

(b) The equilibrium will be shifted to the right by the decreased pressure caused by the reduction in volume.

(c) The equilibrium will be shifted to the left by the increased pressure caused by the increase in volume.

(d) The equilibrium will be shifted to the right by the increased pressure caused by the reduction in volume.

46. In the following equilibrium

$$\frac{1}{2}N_2(g) + O_2(g) \rightleftharpoons NO_2(g) + \text{heat}$$

(a) the equilibrium will shift to the right due to decrease in the concentration of N_2

(b) the equilibrium will shift to the right due to an increase in temperature

(c) the equilibrium will shift to the left due to an increase in volume

(d) the equilibrium will shift to the left due to an increase in the concentration of O_2

47. Consider the following reaction.

$$C(S, \text{diamond}) \rightleftharpoons C(S, \text{graphite}) + \text{heat}$$

Choose the correct option.

(a) An increase in temperature will shift the equilibrium to the right, and so will an increase in pressure.

(b) An increase in temperature will shift the equilibrium to the left and so will an increase in pressure.

(c) An increase in temperature will shift the equilibrium to the left and one in pressure to the right.

(d) Any increase in temperature and pressure will not shift the equilibrium.

48. Consider the reaction

$$2CO(g) + O_2 \rightleftharpoons 2CO_2(g) + \text{heat}$$

Which of the following is incorrect?

(a) The addition of CO and removal of CO_2 at constant volume will shift the equilibrium to the right.

(b) The addition of O_2 and decrease in volume will shift the equilibrium to the right.

(c) The addition of CO and increase in temperature at constant volume not determinable.

(d) The addition of a catalyst and decrease in temperature will shift the equilibrium to the left.

49. At 400 K, the following equilibrium is established.

$$H_2(g) + S(s) \rightleftharpoons H_2S(g);\ K_{eq.} = 7.0 \times 10^{-2}$$

If 0.1 mol of hydrogen and 1.0 mol of sulphur are heated to 400 K in a 1 L vessel, the partial pressure of H_2S at equilibrium is

(a) 28 atm (b) 0.33 atm (c) 2.3 atm (d) 0.933 atm

50. Which of the following equations is valid for a reversible process in a state of equilibrium?

(a) $\Delta G = -RT \ln K_p$ (b) $\Delta G = RT \ln K_p$

(c) $\Delta G° = -RT \ln K_p$ (d) $\Delta G° = RT \ln K_p$

51. Consider the following expression

$$\left(\frac{\partial \ln K_x}{\partial p}\right)_T = -\frac{\Delta n}{p/p°}$$

and apply it to the formation of NH_3 and indicate the correct statement.

(a) K_x increases with increasing pressure

(b) K_x increases with decreasing pressure

(c) K_x decreases with increasing pressure

(d) none of these

(K_x is the equilibrium constant in term of mole-fraction)

52. Consider the expression $\Delta G = -RT\ln K_p + RT\ln Q_p$ and indicate the correct statement at equilibrium

(a) $\Delta G = 0$ $Q_p > K_p$ the equilibrium reaction will shift from left to right

(b) $\Delta G = 0,\ Q_p = K_p$ $Q_p > K_p$ the equilibrium reaction will shift from left to right

(c) $\Delta G = \infty,\ Q_p < K_p$ the equilibrium reaction will shift from right to left

(d) $\Delta G < 0,\ Q_p > K_p$ – do –

where Q_p and K_p term refer to reaction quotient and equilibrium constant at constant pressure respectively.

53. During the mixing of two ideal gases the Free Energy of mixing, ΔG_{mixing} is given by

(a) $\Delta G_{mixing} = nRT(x_A \ln x_A - x_B \ln x_B)$

(b) $\Delta G_{mixing} = nRT(x_A \ln x_A + x_B \ln x_B)$

(c) $\Delta G_{mixing} = nRT(x_A + x_B)\ln x_A \cdot x_B$

(d) $\Delta G_{mixing} = nRTx_A \cdot x_B(\ln x_A + \ln x_B)$

(where x_A, x_B are the mole-fractions of the gases A and B respectively)

54. A plot of the Gibbs energy of a reaction-mixture against the extent of the reaction is

(a) minimum at equilibrium

(b) zero at equilibrium

(c) equal to $\Delta H - T\Delta S$ at equilibrium

(d) maximum at equilibrium

55. In which of the following equilibrium, the equilibrium constant K is not greater than one?

(a) $HCl(g) + NH_3(g) \rightleftharpoons NH_4Cl(s)$

(b) $Fe(s) + H_2S(g) \rightleftharpoons FeS(s) + H_2(g)$

(c) $2H_2O_2(l) + H_2S(g) \rightleftharpoons H_2SO_4(l) + 2H_2(g)$

(d) $2Al_2O_3(s) + 3Si(s) \rightleftharpoons 3SiO_2(s) + 4Al(s)$

56. By which of the following reactions, the equilibrium constant is related to temperature?

(a) $\ln K_2 - \ln K_1 = \dfrac{\Delta H^\circ}{R}\displaystyle\int_{T_1}^{T_2} d\left(\frac{1}{T}\right)$

(b) $\ln K_2 - \ln K_1 = -\dfrac{\Delta H^\circ}{R}\displaystyle\int_{1/T_1}^{1/T_2} d\left(\frac{1}{T^2}\right)$

(c) $\ln K_2 - \ln K_1 = -\dfrac{\Delta H^\circ}{R}\displaystyle\int_{T_1}^{T_2} d\left(\frac{1}{T}\right)$

(d) $\ln K_2 - \ln K_1 = -\dfrac{\Delta H^\circ}{R}\displaystyle\int_{1/T_2}^{1/T_1} d\left(\frac{1}{T}\right)$

57. Which of the following expressions is incorrect?

(a) $\left(\dfrac{\partial \ln K_p}{\partial p}\right)_T = 0$

(b) $\left(\dfrac{\partial \ln K_c}{\partial p}\right)_T = 0$

(c) $\left(\dfrac{\partial \ln K_x}{\partial p}\right)_T = -\dfrac{\Delta n}{(p/p^\circ)}$

(d) All of these

• Type 2 •

Choose the correct options. More than one option is correct.

58. Which of the following statements are incorrect?

(a) For a closed system, S is always maximum at equilibrium.

(b) The addition of a reactant gas to an ideal-gas reaction mixture shifts the equilibrium in such a way that some of the added gas is used up.

(c) In any closed system, G is always minimum at equilibrium.

(d) In the limit $T \to 0$, $\Delta G°$ approaches $\Delta H°$.

59. The expression for the equilibrium constant for an ideal-gas reaction mixture is given by

(a) $\dfrac{d \ln K_c^0}{dT} = \dfrac{\Delta U^0}{RT^2}$ (b) $\left(\dfrac{\partial \ln K_x^0}{\partial T}\right)_p = \dfrac{\Delta S^0}{RT^2}$

(c) $\left(\dfrac{\partial \ln K_x^0}{\partial p}\right)_T = -\dfrac{\Delta n/\text{mol}}{p}$ (d) $\dfrac{d \ln K_p^0}{dT} = \dfrac{\Delta H^0}{RT^2}$

60. The condition for spontaneity in a chemical reaction is

(a) $(\Delta G)_{T,p} \le 0$ (b) $(\Delta U)_{S,V} \le 0$

(c) $(\Delta H)_{S,p} \le 0$ (d) $(\Delta S)_{U,V} \ge 0$

61. In which of the following reactions is $K_p < K_c$?

(a) $CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$

(b) $CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)$

(c) $2BrCl(g) \rightleftharpoons Cl_2(g) + Br_2(g)$

(d) $I_2(g) \rightleftharpoons 2I(g)$

62. The dissociation of phosgene, which occurs according to the reaction

$$COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$$

is an endothermic process. Which of the following will increase the degree of dissociation of $COCl_2$?

(a) Adding Cl_2 to the system

(b) Adding helium to the system

(c) Decreasing the temperature of the system

(d) Reducing the total pressure

63. The equilibrium of which of the following reactions will not be disturbed by the addition of an inert gas at constant volume?

(a) $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

(b) $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

(c) $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$

(d) $C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g)$

64. A box contains CO(g), $Cl_2(g)$ and $COCl_2(g)$ in equilibrium at 1000 K. The removal of CO(g) will

(a) decrease the concentration of $COCl_2$

(b) increase the concentration of Cl_2

(c) increase the concentration of $COCl_2$

(d) reduce the concentration of CO as well as Cl_2

65. An industrial fuel, 'water gas', which consists of a mixture of H_2 and CO can be made by passing steam over red-hot carbon. The reaction is

$$C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g),\ \Delta H = +131\ \text{kJ}$$

The yield of CO and H_2 at equilibrium would be shifted to the product side by

(a) raising the relative pressure of the steam

(b) adding hot carbon

(c) raising the temperature

(d) reducing the volume of the system

66. For the equilibrium $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g),\ \Delta H = -198\ \text{kJ}$, the equilibrium concentration of SO_3 will be affected by

(a) doubling the volume of the reaction vessel

(b) increasing the temperature at constant volume

(c) adding more oxygen to the reaction vessel

(d) adding helium to the reaction vessel at constant volume

67. The following reaction attains equilibrium at high temperature.

$$N_2(g) + 2H_2O(g) + \text{heat} \rightleftharpoons 2NO(g) + 2H_2(g)$$

The yield of NO is affected by

(a) increasing the nitrogen concentration

(b) decreasing the hydrogen concentration

(c) compressing the reaction mixture

(d) none of these

68. $N_2(g) + 3H_2(g) \underset{500°C}{\overset{\text{catalyst}}{\rightleftharpoons}} 2NH_3 + \text{heat}$

In this reaction, the direction of equilibrium will be shifted to the right by

(a) increasing the concentration of nitrogen

(b) compressing the reaction mixture

(c) removing the catalyst

(d) decreasing the concentration of ammonia

69. The dissociation of ammonium carbamate may be represented by the equation

$$NH_4CO_2NH_2(s) \rightleftharpoons 2NH_3(g) + CO_2(g)$$

$\Delta H°$ for the forward reaction is negative. The equilibrium will shift from right to left if there is

(a) a decrease in pressure
(b) an increase in temperature
(c) an increase in the concentration of ammonia
(d) an increase in the concentration of carbon dioxide

Answers

1. d	**2.** c	**3.** b	**4.** b	**5.** d
6. c	**7.** d	**8.** b	**9.** d	**10.** d
11. d	**12.** c	**13.** c	**14.** a	**15.** b
16. c	**17.** d	**18.** c	**19.** c	**20.** a
21. b	**22.** c	**23.** b	**24.** a	**25.** d
26. a	**27.** b	**28.** d	**29.** b	**30.** c
31. d	**32.** d	**33.** d	**34.** b	**35.** a
36. a	**37.** c	**38.** a	**39.** a	**40.** b
41. a	**42.** b	**43.** a	**44.** d	**45.** a
46. c	**47.** b	**48.** d	**49.** c	**50.** c
51. a	**52.** b	**53.** b	**54.** a	**55.** d
56. c	**57.** d	**58.** a, b, c	**59.** a, c, d	**60.** a, b, c, d
61. a, b	**62.** b, d	**63.** a, b, c, d	**64.** a, b	**65.** a, c
66. a, b, c	**67.** a, b, c	**68.** a, b, d	**69.** b, c, d	

Hints to More Difficult Problems

2. For the reaction $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$, $\Delta n = -2$.

$K_p = K_c(RT)^{\Delta n} = K_c(RT)^{-2}$

$\Rightarrow \quad K_c = \dfrac{K_p}{(RT)^{-2}}$.

5. Using the equation

$$\log \frac{(K_p)_{40°C}}{(K_p)_{25°C}} = \frac{\Delta H}{2.303R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right),$$

we get $\log 4 = \dfrac{\Delta H}{2.303 \times 8.314}\left(\dfrac{1}{273+25} - \dfrac{1}{273+40}\right)$.

$\therefore \quad \Delta H = 71.67 \text{ kJ mol}^{-1}$.

6. Apply the Le Chatelier principle.

9.
$$\begin{array}{ccccc} A(g) & + & B(g) & \rightleftharpoons & 2C(g) \\ a & & 3 & & 0 \\ a-x & & 3-x & & 2x \end{array}$$

From the question, $2x = 3 \Rightarrow x = 1.5$

$$3 = \frac{(2x)^2}{(a-x)(3-x)}$$

Substituting $x = 1.5$, we get $a = 3.5$.

10.
$$\begin{array}{ccccc} AB(g) & \rightleftharpoons & A(g) & + & B(g) \\ 1 & & 0 & & 0 \\ -1/3 & & +1/3 & & +1/3 \\ 2/3 & & 1/3 & & 1/3 \end{array}$$

$(\Sigma n)_{\text{eqlm}} = \dfrac{2}{3} + \dfrac{1}{3} + \dfrac{1}{3} = \dfrac{4}{3}$.

$$K_p = \frac{p_A p_B}{p_{AB}} = \frac{\dfrac{1/3}{4/3}p\,\dfrac{1/3}{4/3}p}{\dfrac{2/3}{4/3}p} = \frac{1}{8}p.$$

$\therefore \quad p = 8K_p$.

15.
$$\begin{array}{ccccc} NH_4COONH_2(s) & \rightleftharpoons & 2NH_3(g) & + & CO_2(g) \\ & & \frac{2}{3}p & & \frac{1}{3}p \end{array}$$

$$K_p = p_{NH_3}^2 p_{CO_2} = \left(\frac{2}{3}p\right)^2\left(\frac{1}{3}p\right) = \frac{4}{27}p^3 = \frac{4}{27} \times (2)^3 = 1.185.$$

17. Use the van't Hoff equation.

20. Use the formula $\Delta G° = -2.303\, RT \log K_p$ and assume that $T = 298.15$ K. For questions 22, 23 and 24 use the Le Chatelier principle.

25. $\alpha = \dfrac{M_{\text{Th}} - M_{\text{obs}}}{M_{\text{obs}}(n-1)}$.

Molar mass of $N_2O_4 = 92$ g mol^{-1}.

Here, $n = 2$.

$$\alpha = \frac{92.00 - 77.70}{77.70(2-1)} = 0.184 = 18.4\%.$$

31. Use the van't Hoff equation

$$\frac{d \ln K_p}{dT} = \frac{\Delta H°}{RT^2} \quad \text{or} \quad \ln K_p = -\frac{\Delta H}{R}\frac{1}{T} + C.$$

35. For the equilibrium $H_2O(g) \longrightarrow H_2(g) + \frac{1}{2} O_2(g)$

$$K_p = \frac{\alpha^{3/2} p^{1/2}}{\sqrt{2}} \quad p = 1 \text{ atm}.$$

$$\alpha = (\sqrt{2} \cdot k_p)^{2/3} = 0.0205 \approx 2\%.$$

40. For the equilibrium $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$,

$$K_p = \frac{K_x}{p^2}, \quad p = 10.$$

$$K_x = K_p(10)^2 = 100K_p.$$

Questions 42, 43 and 44 can be answered using the equation

$$K_p = \frac{n_C^c \cdot n_D^d}{n_A^a \cdot n_B^b}\left(\frac{p}{\Sigma n}\right)^{\Delta n}$$

At constant volume the equilibrium will not be disturbed.

54. $\left(\dfrac{\partial G_x}{\partial G_{Eq}}\right)_{p,\,T} = \Delta G$ (minimum)

56. Use Van't Hoff equation

57. K_p, K_c are independent of pressure but K_x is related to pressure

61. For reactions (a) and (b), $\Delta n < 1$.
Questions 57 to 62 may be answered by applying the Le Chatelier principle.

❑

13

Chemical Kinetics

• Type 1 •

Choose the correct option. Only one option is correct.

1. The decomposition of nitrogen pentoxide can be represented as

$$N_2O_5(g) \longrightarrow 2NO_2(g) + \frac{1}{2}O_2(g)$$

The rate of the reaction can be expressed as

(a) $-\frac{d[N_2O_5]}{dt} = 2\frac{d[NO_2]}{dt} = \frac{1}{2}\frac{d[O_2]}{dt} = k[N_2O_5]$

(b) $\frac{1}{2}\frac{d[N_2O_5]}{dt} = \frac{1}{2}\frac{d[NO_2]}{dt} = \frac{d[O_2]}{dt} = k[N_2O_5]$

(c) $-\frac{d[N_2O_5]}{dt} = \frac{1}{2}\frac{d[NO_2]}{dt} = 2\frac{d[O_2]}{dt} = k[N_2O_5]$

(d) $-\frac{d[N_2O_5]}{dt} = \frac{1}{2}\frac{d[NO_2]}{dt} = \frac{1}{2}\frac{d[O_2]}{dt} = k[N_2O_5]$

2. The decomposition of azomethane ($C_2H_6N_2$) at a certain temperature in the gas phase follows first-order kinetics. The following are some data for the reaction $C_2H_6N_2(g) \rightarrow C_2H_6(g) + N_2(g)$.

Time (min)	0	15	30	48	75
$[C_2H_6N_2]$ (M)	0.36	0.30	0.25	0.19	0.13

The value of the rate constant is

(a) $0.007\ \text{min}^{-1}$ (b) $0.014\ \text{min}^{-1}$

(c) $0.042\ \text{min}^{-1}$ (d) $0.028\ \text{min}^{-1}$

3. The instantaneous rate of disappearance of the MnO_4^- ion in the following reaction is $4.56 \times 10^{-3}\ \text{M s}^{-1}$.

$$2MnO_4^- + 10I^- + 16H^+ \longrightarrow 2Mn^{2+} + 5I_2 + 8H_2O$$

The rate of appearance of I_2 is

(a) 1.14×10^{-3} M s^{-1} (b) 5.7×10^{-3} M s^{-1}

(c) 4.56×10^{-4} M s^{-1} (d) 1.14×10^{-2} M s^{-1}

4. For a reaction $I^- + OCl^- \rightarrow IO^- + Cl^-$, in an aqueous medium, the rate of the reaction is given by

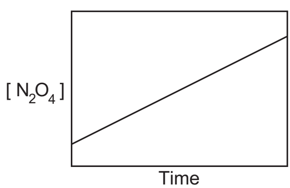
$$\frac{d[IO^-]}{dt} = k\frac{[I^-][OCl^-]}{[OH^-]}$$

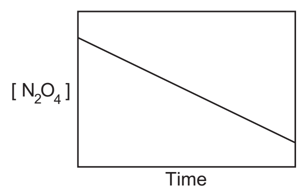
The overall order of the reaction is

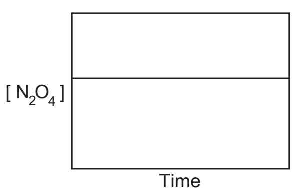
(a) −1 (b) 1

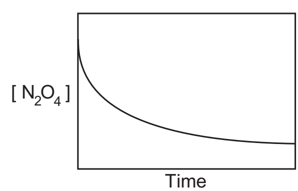
(c) zero (d) 2

5. Which of the following graphs best describes the rate at which N_2O_4 decomposes to NO_2 if the reaction is first-order in N_2O_4?

(a) 

(b) 

(c) 

(d) 

6. The molecularity of the reaction

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$$

is

(a) 2 (b) 3 (c) undefined (d) 1

7. The unit of the rate of reaction is the same as that of the rate constant for a

(a) zero-order reaction (b) first-order reaction

(c) second-order reaction (d) half-order reaction

8. The rate constant for a zero-order reaction is

(a) $k = \frac{c_0}{2t}$ (b) $k = \frac{c_0 - c_t}{t}$

(c) $k = \ln\frac{c_0 - c_t}{2t}$ (d) $k = \frac{c_0}{c_t}$

9. The half-life periods of decomposition of PH_3 for different initial pressures are given below.

p(torr.)	707	79	37.5
$t_{1/2}$(min.)	84	84	84

The order of the reaction is

(a) 1 (b) 0 (c) $\frac{1}{2}$ (d) 2

10. The half-life for a zero-order reaction equals

(a) $\frac{1}{2}\frac{k}{a^2}$ (b) $\frac{a^2}{2k}$ (c) $\frac{2k}{a}$ (d) $\frac{a}{2k}$

where a is the initial concentration.

11. In a chemical reaction A $\rightarrow$ B, it is found that the rate of the reaction doubles when the concentration of A is increased four times. The order of the reaction with respect to A is

(a) 0 (b) $\frac{1}{2}$ (c) 1 (d) 2

12. The rate constant for a first-order reaction is equal to the initial rate of reaction when the initial concentration of the reactant is

(a) 100 M (b) 1×10^{-2} M
(c) 1.0 M (d) 0.1 M

13. The half-life period of a reaction increases fourfold when the initial concentration is increased to four times its value. The order of the reaction is

(a) 1 (b) 4 (c) 0 (d) 2

14. The saponification of ethyl acetate is a

(a) zero-order (b) half-order
(c) second-order (d) third-order

reaction.

15. In a reaction the initial concentrations of the reactants increase fourfold and the rate becomes eight times its initial value. The order of the reaction is

(a) 2.0 (b) 3.5 (c) 2.5 (d) 1.5

16. The rate expression for the reaction A(g) + B(g) $\rightarrow$ C(g) is rate = $kC_A^2 C_B^{1/2}$. What changes in the initial concentrations of A and B will cause the rate of reaction to increase by a factor of eight?

(a) $C_A \times 2; C_B \times 2$ (b) $C_A \times 2; C_B \times 4$
(c) $C_A \times 1; C_B \times 4$ (d) $C_A \times 4; C_B \times 1$

17. Calculate the half-life of the first-order reaction

$$C_2H_4O(g) \longrightarrow CH_4(g) + CO(g)$$

if the initial pressure of $C_2H_4O(g)$ is 80 mm and the total pressure at the end of 20 minutes is 120 mm.

(a) 40 min (b) 120 min
(c) 20 min (d) 80 min

18. In a particular reaction the time required to complete half of the reaction was found to increase 16 times when the initial concentration of the reactant was reduced to one-fourth. What is the order of the reaction?

(a) 1 (b) 4
(c) 2 (d) 3

19. For a first-order reaction, the time required for 99.9% of the reaction to take place is nearly

(a) 10 times that required for half the reaction
(b) 100 times that required for two-thirds of the reaction
(c) 10 times that required for one-fourth of the reaction
(d) 20 times that required for half of the reaction

20. The hydrolysis of ethyl acetate was carried out separately with 0.075 M HCl and 0.075 M H_2SO_4. Which of the following relations is correct?

(a) $k_{H_2SO_4} >> k_{HCl}$ (b) $k_{H_2SO_4} = 2k_{HCl}$
(c) $k_{HCl} > k_{H_2SO_4}$ (d) $k_{H_2SO_4} = 8k_{HCl}$

21. For a reaction following first-order kinetics, which of the following statements are correct?

(a) The time taken for the completion of 50% of the reaction is twice $t_{1/2}$.
(b) A plot of the reciprocal of the concentration of the reactants against time gives a straight line.
(c) The degree of dissociation is equal to $1 - e^{-kt}$.
(d) A plot of $[A]_0/[A]$ versus time gives a straight line.

22. The reaction of NO with Cl_2 follows the equation

$$2NO(g) + Cl_2(g) \longrightarrow 2NOCl$$

The following data were collected.

Initial concentration of NO (mol L^{-1})	Initial concentration of Cl_2(mol L^{-1})	Initial rate of formation of NOCl (mol L^{-1} s^{-1})
0.10	0.10	2.53×10^{-6}
0.10	0.20	5.06×10^{-6}
0.20	0.10	10.10×10^{-6}
0.30	0.10	22.80×10^{-6}

The value of the rate constant is

(a) 2.53×10^{-6} (b) 5.06×10^{-6}

(c) 10.10×10^{-6} (d) 22.80×10^{-6}

$L^2\ mol^{-2}\ s^{-1}$.

23. For the reaction

$$CH_3COCH_3 + Br_2 \xrightarrow{H^+} CH_3COCH_2Br + H^+ + Br^-$$

the following data were collected.

$[CH_3COCH_3]$	$[Br_2]$	$[H^+]$	Rate of disappearance of Br_2 ($M\ s^{-1}$)
0.15	0.025	0.025	6.0×10^{-4}
0.15	0.050	0.025	6.0×10^{-4}
0.15	0.025	0.050	1.2×10^{-3}
0.20	0.025	0.100	3.2×10^{-3}
0.20	0.025	0.025	8.0×10^{-3}

The overall order of the reaction is

(a) 1.5 (b) 4

(c) 5 (d) 2

24. Consider the reaction $X + Y \rightarrow$ products. If the initial concentration of X is increased to four times its original value, keeping the concentration of Y constant, the rate of reaction increases fourfold. When the concentrations of both X and Y become four times their original values, the rate of reaction becomes sixteen times its original value. The observed rate law is

(a) $k[X]^2[Y]^2$ (b) $k[X]^1[Y]^2$

(c) $k[X]^1[Y]^1$ (d) $k[X]^2[Y]^1$

25. An endothermic reaction has a positive internal energy change ΔU. In such a case, what is the minimum value that the activation energy can have?

(a) ΔU (b) $\Delta U = \Delta H + \Delta nRT$

(c) $\Delta U = \Delta H - \Delta nRT$ (d) $\Delta U = E_a + RT$

26. The activation energy of a reaction may be lowered by

(a) decreasing the temperature

(b) increasing the temperature

(c) adding a catalyst

(d) reducing the potential energy

27. In an exothermic reaction $X \rightarrow Y$, the activation energy is 100 kJ mol^{-1} of X. The enthalpy of the reaction is –140 kJ mol^{-1}. The activation energy of the reverse reaction $Y \rightarrow X$ is

(a) 40 kJ mol^{-1}
(b) 340 kJ mol^{-1}
(c) 240 kJ mol^{-1}
(d) 100 kJ mol^{-1}

28. The rate constant, the activation energy and the pre-exponential factor of a chemical reaction at 25°C are $8.0 \times 10^{-4}\ s^{-1}$, 112 kJ mol^{-1} and $4 \times 10^{15}\ s^{-1}$ respectively. The value of the rate constant as $T \rightarrow \infty$ is

(a) $8 \times 10^{16}\ s^{-1}$
(b) $4 \times 10^{4}\ s^{-1}$
(c) $4 \times 10^{15}\ s^{-1}$
(d) $112 \times 10^{12}\ s^{-1}$

29. Which of the following is correct?

(a) Total collision rate $\propto$ mean speed $\propto$ absolute temperature
(b) Total collision rate $\propto \dfrac{1}{\text{mean speed}} \propto \dfrac{1}{\text{absolute temperature}}$
(c) Total collision rate $\propto$ mean speed $\propto$ (absolute temperature)$^{1/2}$
(d) Total collision rate $\propto$ (mean speed)^{2} $\propto$ (absolute temperature)^{3}

30. It is often stated that, near room temperature, a reaction rate doubles if the temperature increases by 10°C. Calculate the activation energy of a reaction that obeys this rule exactly.

(a) 12.4 kcal
(b) 24.8 kcal
(c) 6.2 kcal
(d) 49.6 kcal

31. Which of the following statements is correct for the activation energy of a reaction?

(a) It increases with increase in temperature.
(b) When the activation energy is zero the rate constant is temperature-dependent.
(c) It decreases with decrease in temperature.
(d) It is nearly independent of temperature, over a wide range.

32. In the reaction

$$S + C \underset{K_{-1}}{\overset{K_2}{\rightleftharpoons}} X$$

$$X + R \xrightarrow{K'_2} \text{products} + C$$

where S = substrates, C = catalyst, X = intermediate complex and R = other substrates.

The rate of formation of products is given by $v = K'_2 = [X]\,[R]$. The rate of accumulation of X is given by

(a) $\dfrac{d[C]}{dt} = K'[C][S]$
(b) $\dfrac{d[R]}{dt} = K'[X][R]$

(c) $\frac{d[X]}{dt} = 0$ (d) $\frac{d[X]}{dt} \geq 1$

33. When the activation energies of the forward and reverse reactions are equal, then

(a) $\Delta U = 0,\ \Delta S = 0$ (b) $\Delta U = \infty,\ \Delta S = 0$

(c) $\Delta G = 0,\ \Delta U = 0$ (d) only $\Delta U = 0$

34. A drop of a solution (volume = 0.05 mL) contains 6×10^{-7} mol of H^+. If the rate of disappearance of H^+ is 6.0×10^5 mol L^{-1} s^{-1}, how long will it take for the H^+ in the drop to disappear?

(a) 8.0×10^{-8} s (b) 2.0×10^{-8} s

(c) 6.0×10^{-6} s (d) 2.0×10^{-2} s

35. The reaction $2A \longrightarrow B$ is first-order in A with a rate constant of $2.8 \times 10^{-2}\ s^{-1}$. How long will it take for A to decrease from 0.88 M to 0.14 M?

(a) 50 s (b) 76 s

(c) 66 s (d) 44 s

36. Inversion of sucrose occurs under

(a) general acid-base catalysis (b) general acid catalysis

(c) general base catalysis (d) specific acid catalysis

37. In the Arrhenius equation $k = A \exp(-E_A/RT)$, the rate constant

(a) decreases with increasing activation energy and increases with temperatue

(b) increases with activation energy and temperature

(c) decreases with activation energy and temperature

(d) increases with activation energy and decreasing temperature

38. Nickel as a catalyst is said to be geometrically effective when ethylene is adsorbed on it because

(a) the closest distance between the nickel atoms is greater than the C—C distance in ethylene

(b) the closest distance between the nickel atoms is less than the C—C distance in ethylene

(c) the closest distance between the nickel atoms is equal to the C—C distance in ethylene

(d) the closest distance between the nickel atoms is less than that between the nickel and carbon atoms after adsorption

39. The rate of the reaction A $\longrightarrow$ B is given by

(a) $-\frac{1}{V}\frac{dn_A}{dt} = \frac{1}{V}\frac{dn_B}{dt}$ (b) $\frac{p}{RT}\frac{dn_A}{dt} = -\frac{p}{RT}\frac{dn_B}{dt}$

(c) $-\frac{1}{[A]}\frac{dn_A}{dV} = +\frac{1}{[B]}\frac{dn_B}{dV}$ (d) $-\frac{dV_A}{dt} = +\frac{dV_B}{dt}$

where n_A and n_B are the number of moles of A and B and V_A and V_B are their volumes, respectively.

40. Consider the dehydrogenation of 2-propanol,

$$CH_3CHOHCH_3(l) \longrightarrow CH_3COCH_3(l) + H_2(g)$$

The following data were obtained about this reaction. (Assume the volume of the reaction mixture to be 1 dm^3.)

Time (min)	0	5	10	15
[Acetone] mol L^{-1}	0	0.3	0.6	0.9

The initial rate of the reaction was

(a) 0.03 mol dm^{-3} min^{-1} (b) 0.06 mol dm^{-3} min^{-1}

(c) 0.09 mol dm^{-3} min^{-1} (d) 0.12 mol dm^{-3} min^{-1}

41. The decomposition of nitrogen pentoxide is a first-order reaction

$$\left(N_2O_2 \longrightarrow 2NO_2 + \frac{1}{2}O_2\right).$$

The rate of this reaction is given by

$$\frac{-dc_{N_2O_5}}{dt} = \frac{1}{2}\frac{dc_{NO_2}}{dt} = 2\frac{dc_{O_2}}{dt} = K_1 c_{N_2O_5}$$

Then

$$-\frac{dc_{N_2O_5}}{dt} = k_1 c_{N_2O_5} = k_1 c_{N_2O_5}$$

$$-\frac{dc_{NO_2}}{dt} = 2k_1 c_{N_2O_5} = k_2' c_{N_2O_5}$$

$$-\frac{dc_{O_2}}{dt} = \frac{1}{2}k_1 c_{N_2O_5} = k_1'' c_{N_2O_5}$$

Choose the correct option.

(a) $k_1 = 2k_1' = k_1''$ (b) $k_1 = k_1' = k_1''$

(c) $4k_1 = 2k_1' = k_1''$ (d) $4k_1 = k' = 2k_1''$

42. The rate expression for the second-order reaction A + B $\longrightarrow$ products is given by

$$K_2 t = \frac{1}{a-b}\ln\frac{b(a-x)}{a(b-x)}$$

Bear in mind the following data.

$t = 0$	a	b
$t = t$	$a - x$	$b - x$

where a = concentration of A
and b = concentration of B.

When $a >> b$, this expression will become

(a) zero-order (b) third-order
(c) half-order (d) first-order

43. A sample of ammonia decomposes on a tungsten wire at 1135 K. At constant volume, the following results were obtained.

Pressure (torr)	210	221	232	255	277
Time (s)	0	100	200	400	600

The rate constant for the reaction is

(a) 0.22 torr s^{-1} (b) 0.33 torr s^{-1}
(c) 0.11 torr s^{-1} (d) 0.44 torr s^{-1}

44. The unit of the rate constant depends upon the

(a) temperature of the reaction
(b) activation energy of the reaction
(c) molecularity of the reaction
(d) order of the reaction

45. The rate constant for two parallel reactions were found to be $1.0 \times 10^{-2}\ dm^3\ mol^{-1}\ s^{-1}$ and $3.0 \times 10^{-2}\ dm^3\ mol^{-1}\ s^{-1}$. If the corresponding energies of activation of the parallel reactions are 60.0 kJ mol^{-1} and 70.0 kJ mol^{-1} respectively, what is the apparent overall energy of activation?

(a) 130.0 kJ mol^{-1} (b) 67.5 kJ mol^{-1}
(c) 100.0 kJ mol^{-1} (d) 65.0 kJ mol^{-1}

46. At 400 K the half-life of a sample of a gaseous compound initially at 56.0 kP_a is 340 s. When the pressure is 28.0 kP_a, the half-life is 170 s. The order of the reaction is

(a) 0 (b) 2
(c) 1 (d) $\frac{1}{2}$

47. Consider the reaction mechanism

$$A_2 \rightleftharpoons 2A \text{ (fast)}$$
$$A + B \longrightarrow P \text{ (slow)}$$

where A is the intermediate. The rate law for the reaction is

(a) $k_2[A][B]$ (b) $k_2 k^{1/2}[A_2]^{1/2}[B]$
(c) $k_2 k^{1/2}[A][B]$ (d) $k_2 k^{1/2}[A]^2[B]$

48. Consider the following reactions at 300 K.

$A \longrightarrow B$ (uncatalysed reaction)

$A \xrightarrow{\text{catalyst}} B$ (catalysed reaction)

The activation energy is lowered by 8.314 kJ mol^{-1} for the catalysed reaction. The rate of this reaction is

(a) 15 times (b) 38 times (c) 22 times (d) 28 times

that of the uncatalyzed reaction.

49. Aqueous NH_4NO_2 decomposes according to the first-order reaction

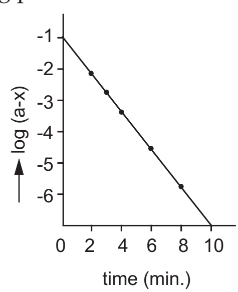
$$NH_4NO_2(aq) \longrightarrow N_2(g) + 2H_2O(l)$$

After 20 minutes the volume of N_2 collected during such a reaction is 20 mL, and that collected after a very long time is 40 mL. The rate constant for the reaction is

(a) 1.435×10^{-2} min^{-1} (b) 3.466×10^{-2} min^{-1}

(c) 3.465×10^{-2} min^{-1} (d) 6.93 min^{-1}

50. The conversion of vinyl allyl ether to pent-4-enol follows first-order kinetics. The following plot is obtained for such a reaction.



The rate constant for the reaction is

(a) 4.6×10^{-2} s^{-1} (b) 1.2×10^{-2} s^{-1}

(c) 2.3×10^{-2} s^{-1} (d) 8.4×10^{-2} s^{-1}

51. $N_2O_2(g) \longrightarrow 2NO$ is a first-order reaction in terms of the concentration of $N_2O_2(g)$. Which of the following is valid, $[N_2O_2]$ being constant?

(a) $[NO] = [N_2O_2]_0\, e^{-kt}$ (b) $[NO] = [N_2O_2]_0\,(1 - e^{-kt})$

(c) $[NO] = [N_2O_2]_0\,(e^{-kt} - 1)$ (d) $[NO] = [N_2O_2]_0\,(1 - e^{-kt})$

52. The reaction $A(g) + 2B(g) \rightarrow C(g) + D(g)$ is an elementary process. In an experiment involving this reaction, the initial partial pressures of A and B are $p_A = 0.60$ atm and $p_B = 0.80$ atm respectively. When $p_C = 0.20$ atm, the rate of the reaction relative to the initial rate is

(a) $\frac{1}{6}$ (b) $\frac{1}{12}$ (c) $\frac{1}{36}$ (d) $\frac{1}{18}$

53. Which of the following statements is correct?

(a) The order of a reaction must be a positive integer.

(b) A second-order reaction is also bimolecular.

(c) The order of a reaction increases with temperature.

(d) All bimolecular reactions are of the second order.

54. For the reaction $A + B \longrightarrow C$ the rate constant for the second-order forward reaction is $k_2 = 10.00 \exp.\left(-\frac{90500}{RT}\right)$ $dm^3\ mol^{-1}\ s^{-1}$. The pre-exponential factor and activation energy are, respectively,

(a) $10^{10}\ dm^3\ mol^{-1}\ s^{-1}$ and -90.50 kJ mol^{-1}

(b) log 10 $dm^3\ mol^{-1}\ s^{-1}$ and -45.25 kJ mol^{-1}

(c) 10 $dm^3\ mol^{-1}\ s^{-1}$ and 90.50 kJ mol^{-1}

(d) 10 $dm^3\ mol^{-1}\ s^{-1}$ and -90.25 kJ mol^{-1}

55. On thermal decomposition, 2-nitropropane yields propylene, and the rate constant is given by the relationship

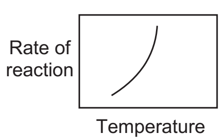
$$k = 1.11 \times 10^{11} \exp.\left(-\frac{164438}{8.314T}\right) s^{-1}.$$

What is the half-life of this reaction at 300°C?

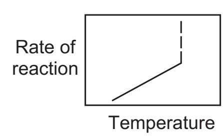
(a) 5964 s (b) 6964 s

(c) 9654 s (d) 4964 s

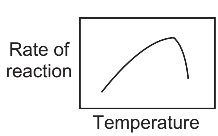
56. (I)



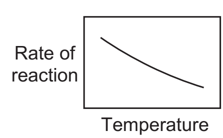
(II)



(III)



(IV)



Which of these graphs represents an enzyme reaction?

(a) II (b) III (c) I (d) IV

57. What happens when the temperature of a solution is increased from 25°C to 65°C?

(a) The rate of the reaction remains unchanged and the rate constant *k* decreases.

(b) The rate of the reaction increases and the rate constant *k* decreases.

(c) The rate of the reaction decreases and so does the rate constant *k*.

(d) The rate of the reaction increases and so does the rate constant *k*.

58. The rate law for the reaction

$$2H_2(g) + 2NO(g) \longrightarrow N_2(g) + H_2O(g)$$

is $\dfrac{d[N_2]}{dt} = k[H_2][NO]^2$.

Which of the following mechanisms is consistent with the rate law?

(a) $H_2(g) + 2NO(g) \xrightarrow{k_1} N_2O(g) + H_2O(g)$

(b) $H_2(g) + N_2O(g) \xrightarrow{k_2} N_2(g) + H_2O(g)$

(c) $H_2O(g) + NO(g) \xrightarrow{k_3} H_2(g) + NO_2(g)$

(d) $H_2(g) + 2NO(g) \xrightarrow{k_4} N_2(g) + H_2O(g) + \dfrac{1}{2}O_2(g)$

59. In the decomposition of $N_2O_5(g)$, i.e.,

$$2N_2O_5(g) \xrightarrow{k_{obs}} 4NO_2(g) + O_2(g)$$

the observed rate law is given by

$$\frac{d[O_2]}{dt} = k_{obs}[N_2O_5].$$

Which of the following proposed mechanisms is consistent with the rate law?

(a) $N_2O_5(g) \xrightarrow{k_1} N_2O_3(g) + O_2(g)$

(b) $N_2O_5(g) \xrightarrow{k_2} NO_2(g) + NO_3(g)$

(c) $NO_2(g) + NO_3(g) \xrightarrow{k_3} NO(g) + NO_2(g) + O_2(g)$

(d) $NO_3(g) + NO(g) \xrightarrow{k_4} 2NO_2(g)$

• Type 2 •

Choose the correct options. More than one option is correct.

60. Which of the following statements are correct?

(a) The order of a reaction is the sum of the components of all the concentration terms in the rate equation.

(b) The order of a reaction with respect to one reactant is the ratio of the change of logarithm of the rate of the reaction to the change in the logarithm of the concentration of the particular reactant, keeping the concentrations of all other reactants constant.

(c) Orders of reactions can be whole numbers or fractional numbers.

(d) The order of a reaction can only be determined from the stoichiometric equation for the reaction.

61. Which of the following statements are correct?

(a) The rate of the reaction involving the conversion of ortho-hydrogen to parahydrogen is $-\dfrac{d[H_2]}{dt} = k[H_2]^{3/2}$.

(b) The rate of the reaction involving the thermal decomposition of acetaldehyde is $k[CH_3CHO]^{3/2}$.

(c) In the formation of phosgene gas from CO and Cl_2, the rate of the reaction is $k[CO][Cl_2]^{1/2}$.

(d) In the decomposition of H_2O_2, the rate of the reaction is $k[H_2O_2]$.

62. Which of the following isomerization reactions is of the first order?

(a) cyclopropane $\longrightarrow$ propane

(b) *cis*-but-2-ene $\longrightarrow$ *trans*-but-2-ene

(c) vinyl allyl ether $\longrightarrow$ *pent*-4-enal

(d) $CH_3NC \longrightarrow CH_3CN$

63. Which of the following reactions is of the first order?

(a) The decomposition of ammonium nitrate in an aqueous solution

(b) The inversion of cane-sugar in the presence of an acid

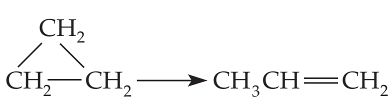
(c) The acidic hydrolysis of ethyl acetate

(d) All radioactive decays

64. Which of the following are examples of unimolecular reactions?

(a) $O_3 \rightarrow O_2 + O$

(b)



(c) $NO + O_3 \rightarrow NO_2 + O_2$

(d) $O + NO + N_2 \rightarrow NO_2 + N_2$

65. The calculation of the pre-exponential factor is based on the

(a) idea that, for a reaction to take place, the reactant species must come together

(b) calculation of the molecularity of the reaction

(c) idea that the reactant species must come together, leading to the formation of the transition state which then transforms into the products

(d) calculation of the order of the reaction

66. Which of the following are examples of pseudo-unimolecular reactions?

(a) $CH_3CO_2C_2H_5 + H_2O \xrightarrow{H^+} CH_3CO_2H + C_2H_5OH$

(b) $C_{12}H_{22}O_{11} + H_2O \xrightarrow{H^+} \underset{\text{(glucose)}}{C_6H_{12}O_6} + \underset{\text{(fructose)}}{C_6H_{12}O_6}$

(c) $CH_3COCl + H_2O \longrightarrow CH_3CO_2H + HCl$

(d) $CH_3CO_2C_2H_5 + H_2O \xrightarrow{OH^-} CH_3CO_2H + C_2H_5OH$

67. In which of the following ways does an activated complex differ from an ordinary molecule?

(a) It is quite unstable and has no independent existence.

(b) ΔH°_f is probably positive.

(c) The system has a greater vibrational character.

(d) The system has no vibrational character.

68. The basic theory behind Arrhenius's equation is that

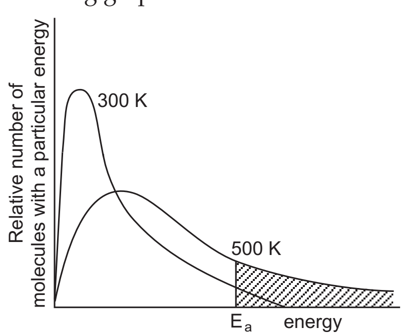
(a) the number of effective collisions is proportional to the number of molecules above a certain threshold energy

(b) as the temperature increases, so does the number of molecules with energies exceeding the threshold energy

(c) the rate constant is a function of temperature

(d) the activation energy and pre-exponential factor are always temperature-independent

69. The distribution of molecular kinetic energy at two temperature is as shown in the following graph.



Which of the following conclusions are correct?

(a) The number of molecules with energy E_a or greater is proportional to the shaded area for each temperature.

(b) The number of molecules with energy E_a or less is proportional to the shaded area for each temperature.

(c) The number of molecules with energy E_a is the mean of all temperatures.

(d) The graph follows the Maxwell–Boltzmann energy distribution law.

70. In Arrhenius's equation, $k = A \exp\left(-\frac{E_a}{RT}\right)$. A may be termed as the rate constant at

(a) very low temperature

(b) very high temperature

(c) zero activation energy

(d) the boiling temperature of the reaction mixture

Answers

1. c	**2.** b	**3.** d	**4.** b	**5.** d
6. c	**7.** a	**8.** b	**9.** a	**10.** d
11. b	**12.** c	**13.** c	**14.** c	**15.** d
16. b	**17.** c	**18.** d	**19.** a	**20.** c
21. c	**22.** a	**23.** d	**24.** c	**25.** a
26. c	**27.** c	**28.** c	**29.** c	**30.** a
31. d	**32.** c	**33.** d	**34.** b	**35.** c
36. d	**37.** a	**38.** a	**39.** a	**40.** b
41. b	**42.** d	**43.** c	**44.** d	**45.** b
46. a	**47.** b	**48.** d	**49.** b	**50.** c
51. d	**52.** a	**53.** d	**54.** c	**55.** a
56. b	**57.** d	**58.** a	**59.** b	**60.** a, b, c
61. a, b, c, d	**62.** a, b, c, d	**63.** a, b, c, d	**64.** a, b	**65.** a, c
66. a, b, c	**67.** a, c	**68.** a, b, c	**69.** a, d	**70.** b, c

Hints to More Difficult Problems

2. Use the formula $k = \frac{2.303}{t} \log \frac{a}{a-x}$.

8. For a zero-order reaction, $-\frac{d[A]}{dt} = k$.

$$-\int_{C_0}^{C_t} d[A] = k\int_{t=0}^{t=0} dt.$$

$$C_0 - C_t = kt \Rightarrow k = \frac{C_0 - C_t}{t}.$$

10. $k = \dfrac{C_0 - C}{t}\cdot$

At $t_{1/2}$, $C = \dfrac{1}{2}C_0$ and $t = t_{1/2}$ or $k = \dfrac{C_0 - \frac{1}{2}C_0}{t_{1/2}} = \dfrac{\frac{1}{2}C_0}{t_{1/2}}\cdot$

$\therefore \quad t_{1/2} = \dfrac{C_0}{2k} = \dfrac{a}{2k} \quad [C_0 = a].$

15. Rate $= KC^n$ or $r = KC^n$. (1)

$8r = K(4C)^n$. (2)

Dividing Equation (2) by Equation (1), we get

$2^3 = 2^{2n}$ or $2n = 3 \Rightarrow n = 1.5$.

17.

	$C_2H_4O(g)$	$\longrightarrow$	$CH_4(g)$	+	$CO(g)$
At $t = 0$	p_0		0		0
At $t = t$	$p_0 - p$		p		p

According to the question,

$p_0 - p + p = 120$ mm or $p_0 + p = 120$ mm or $p = 120 - 80 = 40$ mm.

For a first-order reaction,

$$k = \frac{1}{t}\ln\frac{p_0}{p_0 - p} = \frac{1}{20}\ln\frac{80}{80-40} = \frac{1}{20}\ln 2. \qquad (1)$$

But we know that $t_{1/2} = \dfrac{\ln 2}{k}\cdot$ (2)

From Equations (1) and (2),

$$k = \frac{1}{20}kt_{1/2} \Rightarrow t_{1/2} = 20 \text{ min.}$$

19. $k = \dfrac{1}{t}\ln\dfrac{100}{100 - 99.9} = \dfrac{1}{t}\ln\dfrac{100}{0.1}$

or $\dfrac{\ln 2}{t_{1/2}} = \dfrac{1}{t}\ln 10^3$

or $\dfrac{\log 2}{t_{1/2}} = \dfrac{1}{t}\times \log 10^3 = \dfrac{3}{t}\cdot$

$$t_{1/2} = \frac{\log 2}{3}\times t = \frac{0.30103}{3}\times t \approx 0.10t.$$

$\therefore \quad t = 10\, t_{1/2}$.

21. $k = \dfrac{1}{t}\ln\dfrac{a}{a-x} \Rightarrow \ln\dfrac{a}{a-x} = kt.$

$\Rightarrow \quad \ln\dfrac{a-x}{a} = -kt \Rightarrow a - x = ae^{-kt}$

or $\quad x = a(1 - e^{-kt}) \Rightarrow \dfrac{x}{a} = (1 - e^{-kt}).$

28. When $T \to \infty$ then $k = A$.

$\therefore \quad k = 4 \times 10^{15}\ s^{-1}$.

33. $\overrightarrow{E}_a - \overleftarrow{E}_a = \Delta U$. When $\overrightarrow{E}_a = \overleftarrow{E}_a$ then $\Delta U = 0$.

34. $[H^+] = \dfrac{6 \times 10^{-7}\ \text{mol}}{0.05 \times 10^{-3}\ \text{L}} = 1.2 \times 10^{-2}\ \text{M}$

or $\quad r = \dfrac{\Delta x}{\Delta t} \quad$ or $\ \Delta T = \dfrac{\Delta x}{r} = \dfrac{1.2 \times 10^{-2}\ \text{M}}{6 \times 10^{5}\ \text{M s}^{-1}}$.

$\therefore \quad t = 2 \times 10^{-8}$ s.

40. Rate $= \dfrac{dC}{dt} = \dfrac{0.6 - 0.3}{10 - 5} \quad$ or $\quad \dfrac{0.9 - 0.6}{15 - 10} = 0.06$ mol dm^{-3} s^{-1}.

45. $E_a = \dfrac{K_2 E_a + K_2' E_a'}{K_2 + K_2'} = \dfrac{1.0 \times 10^{-2} \times 60 + 3.0 \times 10^{-2} \times 70}{1.0 \times 10^{-2} + 3.0 \times 10^{-2}}$

$= 67.5$ kJ mol^{-1}

48. $k_{\text{uncatl}} = A[-\exp(E_{\text{uncat}}/RT)]$

$k_{\text{catl}} = A[-\exp(E_{\text{uncatl}}/RT)]$

$k_{\text{uncatl}} = \exp[-(E_{\text{uncatl}} - E_{\text{catl}}/RT]$

$k_{\text{catl}} = \exp(-8.314 \times 10^3/8.314 \times 300) = e^{-3.33}$

or $\quad \dfrac{k_{\text{catl}}}{k_{\text{uncatl}}} = e^{3.33} \approx 28$

53. Represent the reaction in terms of an elementary reaction.

58. Experimental finding

❑

14

Ionic Equilibrium

• *Type 1* •

Choose the correct option. Only one option is correct.

1. If the H^+ ion concentration of a solution is increased to ten times its initial value, its pH will

(a) increase by one (b) remain unchanged

(c) decrease by one (d) increase by ten

2. What will be the H^+ ion concentration in a solution prepared by mixing 50 mL of 0.20 M NaCl, 25 mL of 0.10 M NaOH and 25 mL of 0.30 M HCl?

(a) 0.5 M (b) 0.05 M

(c) 0.02 M (d) 0.10 M

3. Determine the pH of the solution that results from the addition of 20.00 mL of 0.01 M $Ca(OH)_2$ to 30.00 mL of 0.01 M HCl.

(a) 11.30 (b) 10.53

(c) 2.70 (d) 8.35

4. To 250 mL of M/50 H_2SO_4, 40.0 g of solid NaOH is added and the resulting solution is diluted to 1.0 L. The pH of the resulting solution is

(a) 12.00 (b) 11.25 (c) 11.95 (d) 12.95

5. The pH of milk lies between

(a) 6.6 and 6.9 (b) 2.60 and 4.40

(c) 7.0 and 7.5 (d) 7.35 and 7.45

6. Which of the following is correct?

(a) K_a (weak acid) · K_b (conjugate weak base) = K_w

(b) K_a (strong acid) · K_b (conjugate weak base) = K_w

(c) K_a (weak acid) · K_b (weak base) = K_w

(d) K_a (weak acid) · K_b (conjugate strong base) = K_w

7. Which of the following concentrations has the largest degree of dissociation for a weak acid?

(a) 1.0 M (b) 0.5 M
(c) 0.10 M (d) 0.01 M

8. A given weak acid (0.01 M) has $pK_a = 6$. The pH of the solution is

(a) 3 (b) 4
(c) 5 (d) 6

9. Two weak solutions are isohydric when their

(a) hydrogen-ion concentrations are the same before mixing
(b) hydrogen-ion concentrations are the same before and after mixing
(c) degrees of dissociation are the same
(d) chemical properties are the same

10. An acidic solution (0.1 M) of a salt is saturated with H_2S (0.1 M). The concentration of H_2S is, given $K_1K_2 = 10^{-21}$,

(a) 10^{-22} (b) 10^{-19}
(c) 10^{-20} (d) 10^{-18}

11. Which of the following solutions can be titrated with HCl as well as NaOH?

(a) Glycine (b) Pyruvic acid
(c) Triethylamine (d) Aniline

12. The pH of 10^{-10} M H_2SO_4 will be almost

(a) 4 (b) 7
(c) 6 (d) 0

13. How much water should be added to 10.0 g of acetic acid to give a hydrogen-ion concentration equal to 1.0×10^{-3} M (given $pK_a = 4.74$)?

(a) 4 L (b) 6 L
(c) 5 L (d) 3 L

14. The pH of an HCl solution is 2.0. Sufficient water is added to it to make the pH of the new solution 5.0. The hydrogen-ion concentration is reduced

(a) tenfold (b) sevenfold
(c) thousandfold (d) hundredfold

15. Calculate the pH of a solution prepared by mixing 2.0 mL of a strong acid (HCl) solution of pH 3.0 and 3.0 mL of a strong base (NaOH) of pH 10.0.

(a) 2.5 (b) 3.5
(c) 4.5 (d) 6.5

16. The dissociation constant of monobasic acids A, B and C are 10^{-4}, 10^{-6} and 10^{-10} respectively. The concentration of each is 0.1 M. Which of the following has been arranged in order of increasing pH?

(a) $A < B < C$ (b) $C < A < B$
(c) $B < C < A$ (d) $B < A \approx C$

17. Among the following, which causes the greatest change in pH on addition to 50 mL of a 0.2 M malonic acid solution?

(a) 25 mL of 0.02 M malonic acid
(b) 25 mL of 0.02 M NaOH solution
(c) 25 mL of 0.02 M HCl solution
(d) 50 mL of 0.2 M acetic acid

18. An acetic acid and sodium acetate buffer has $pH = 5.36$. The ratio of concentrations [OAc]/ [HOAc] is (pK_a of acetic acid = 4.76)

(a) 6 : 1 (b) 4 : 3
(c) 1 : 1 (d) 4 : 1

19. Calculate the pH at the equivalence point in the titration of 25 mL of 0.10 M formic acid with a 0.1 M NaOH solution (given that pK_a of formic acid = 3.74).

(a) 4.74 (b) 8.74 (c) 8.37 (d) 6.06

20. A buffer solution is used in the

(a) preparation of chrome alum
(b) removal of PO_4^{3-} ions in qualitative analysis
(c) precipitation of $Zn(OH)_2$ from $ZnSO_4$
(d) determination of the ionic product of water

21. Which of the following mixture solutions has $pH = 1.0$?

(a) 100 mL $\frac{N}{10}$ HCl + 100 mL $\frac{M}{10}$ NaOH

(b) 55 mL $\frac{M}{10}$ HCl + 45 mL $\frac{M}{10}$ NaOH

(c) 10 mL $\frac{M}{10}$ HCl + 90 mL $\frac{M}{10}$ NaOH

(d) 75 mL $\frac{M}{5}$ HCl + 25 mL $\frac{M}{5}$ NaOH

22. Fear or excitement generally causes one to breathe rapidly and results in the decrease of CO_2 concentration in one's blood. In what way does this change the pH of blood?

(a) It increases. (b) It decreases.
(c) There is no change in the pH. (d) The pH level is adjusted at 7.

23. The pK_a of acetyl salicyclic acid (aspirin) is 3.5. The pH of gastric juice in the human stomach is about 2–3 and that in the small intestine about 8.0. Aspirin will be

(a) unionized in the small intestine and in the stomach

(b) completely ionized in the small intestine and in the stomach

(c) ionized in the stomach and almost unionized in the small intestine

(d) ionized in the small intestine and almost unionized in the stomach

24. At 25°C, the dissociation constants of CH_3COOH and NH_3 in aqueous solutions are almost the same. The pH of a solution of 0.01 M CH_3CO_2H is 4.0 at 25°C. The pH of a 0.01 M NH_3 solution at the same temperature is

(a) 3.0 (b) 4.0

(c) 10.0 (d) 11.0

25. The pH of blood does not appreciably change by a small addition of acid or a base because blood

(a) contains serum protein which acts as a buffer

(b) contains iron as a part of the molecule

(c) can be easily coagulated

(d) is a body fluid

26. What will be the K_b value of a weak base (BOH) of which a 0.1 M solution has a pH of 8, when it is half neutralized with 0.1 M HNO_3?

(a) 10^{-8} (b) 10^{-4}

(c) 10^{-6} (d) 10^{-7}

27. For the precipitation of cations of group IV in qualitative analysis, the medium is made alkaline before passing H_2S gas. The medium is made alkaline because this helps

(a) suppress the ionization of H_2S

(b) increase the ionization of H_2S

(c) increase the ionization of metal salts

(d) reduce the ionization of metal salts

28. The solubility of AgCl in 0.1 M NaCl will

(a) increase

(b) decrease

(c) remain unchanged

(d) AgCl will dissociate completely.

29. The solubility of a salt A_2B_3 is 1.0×10^{-3} M. Its solubility product is

(a) 1.08×10^{-13} (b) 1.08×10^{-15}

(c) 1.08×10^{-10} (d) 1.08×10^{-17}

30. M_2SO_4 (M^+ is a monovalent metal ion) has a K_{sp} of 3.2×10^{-5} at 25°C. The maximum concentration of SO_4^{2-} ions possible in a saturated solution of this solid is

(a) 4×10^{-4} M (b) 5×10^{-6} M

(c) 2×10^{-2} M (d) 8×10^{-3} M

31. The pH of an aqueous solution of $Ba(OH)_2$ is 10.0. If the K_{sp} of $Ba(OH)_2$ is 1×10^{-9} then the concentration of Ba^{2+} ions in the solution is

(a) 1×10^{-4} M (b) 1×10^{-6} M

(c) 1×10^{-2} M (d) 1×10^{-1} M

32. The K_{sp} of $Mg(OH)_2$ is 1×10^{-12}. 0.01 M $MgCl_2$ will precipitate at the limiting pH

(a) 3 (b) 9 (c) 12 (d) 8

33. $M(OH)_x$ has a K_{sp} of 4×10^{-9} and its solubility is 10^{-3} M. The value of x is

(a) 4 (b) 1 (c) 3 (d) 2

34. When equal volumes of the following solutions are mixed, the precipitation of AgCl($K_{sp} = 1.8 \times 10^{-10}$) will occur with

(a) 10^{-4} M (Ag^+) and 10^{-4} M (Cl^-)

(b) 10^{-5} M (Ag^+) and 10^{-5} M (Cl^-)

(c) 10^{-5} M (Ag^+) and 10^{-6} M (Cl^-)

(d) 10^{-10} M (Ag^+) and 10^{-10} M (Cl^-)

35. Why does only As^{3+} get precipitated as As_2S_3 and not Zn^{2+} as ZnS when H_2S is passed through an acidic solution containing As^{3+} and Zn^{2+}?

(a) The solubility product of As_2S_3 is less than that of ZnS.

(b) Enough As^{3+} ions are present in an acidic medium.

(c) A zinc salt does not ionize in an acidic medium.

(d) The solubility product changes in the presence of an acid.

36. A solution containing NH_4Cl and NH_3 has a hydroxide-ion concentration of 10^{-6} M. Which of the following hydroxides may be precipitated when this solution is added to an equal volume of a 0.1 M solution of a metal ion?

(a) $Ba(OH)_2$ ($K_{sp} = 1.0 \times 10^{-4}$) (b) $Ca(OH)_2$ ($K_{sp} = 2.2 \times 10^{-5}$)

(c) $Mg(OH)_2$ ($K_{sp} = 3.0 \times 10^{-12}$) (d) $Fe(OH)_2$ ($K_{sp} = 8.0 \times 10^{-16}$)

37. What is the maximum possible concentration of Ni^{2+} ions in a solution containing 0.15 M HCl and 0.10 M H_2S? Given that $K_{sp}(NiS) = 2 \times 10^{-21}$ and $[S^{2-}]_{H_2S} = 4 \times 10^{-21}$.

(a) 0.65 M (b) 0.45 M (c) 0.10 M (d) 0.15 M

38. 50 mL of a solution containing 10^{-3} mol of Ag^+ is mixed with 50 mL of a 0.1 M HCl solution. How much Ag^+ remains in solution (K_{sp} of AgCl $= 1.0 \times 10^{-10}$)?

(a) 2.5×10^{-9} (b) 2.5×10^{-7}

(c) 2.5×10^{-8} (d) 2.5×10^{-10}

39. At a certain temperature, a saturated solution of $Zn(OH)_2$ has a pH of 8.63. The value of K_{sp} of $Zn(OH)_2$ at this temperature is

(a) 4.0×10^{-18} (b) 3.9×10^{-28}

(c) 3.9×10^{-17} (d) 2.0×10^{-19}

40. Which of the following will not hydrolyse in an aqueous solution?

(a) A salt of a strong acid and a strong base

(b) A salt of a strong acid and a weak base

(c) A salt of a weak acid and a strong base

(d) A salt of a weak acid and a weak base

41. Which of the following salts will produce a neutral solution in water?

(a) CH_3COONa (b) CH_3COONH_4

(c) $(NH_4)_2CO_3$ (d) $HCOONH_4$

42. When a 0.20 M solution of acetic acid is neutralized with 0.20 M NaOH in 0.50 L of water, the pH of the resulting solution will be (given that pK_a for $CH_3COOH = 4.74$)

(a) 12.67 (b) 7.87

(c) 8.87 (d) 7.00

43. Equivalent amounts of aqueous solutions of a weak acid and a weak base have a dissociation constant of 5.0×10^{-7} each. The percentage of hydrolysis of the salt formed by them is

(a) 40 (b) 60

(c) 50 (d) 25

44. Assuming complete dissociation of solutes, calculate the pH of the solution obtained by mixing equal volumes of $N/10$ NaOH and $N/20$ HCl.

(a) 7.6 (b) 12.4

(c) 1.6 (d) 13.4

45. If pK_b for the fluoride ion at 25°C is 10.83, the ionization constant of hydrofluoric acid in water at this temperature is

(a) 1.74×10^{-5} (b) 3.52×10^{-3}

(c) 6.76×10^{-4} (d) 5.38×10^{-2}

46. Calculate the molar solubility of $Fe(OH)_2$ at a pH of 8.00 [K_{sp} of $Fe(OH)_2 = 1.6 \times 10^{-14}$].

(a) 0.06 (b) 0.016 (c) 0.010 (d) 0.16

47. Calculate the molar solubility of AgCl in a 1-L solution which contains 10.0 g of $CaCl_2$ [$K_{sp}(AgCl) = 1.6 \times 10^{-10}$].

(a) 8.9×10^{-10} (b) 8.9×10^{-11}

(c) 8.9×10^{-9} (d) 8.9×10^{-12}

48. K_1 and K_2 for oxalic acid are 6.5×10^{-2} and 6.1×10^{-5} respectively. What will be [HO^-] in a 0.01 M solution of sodium oxalate?

(a) 9.6×10^{-6} (b) 1.4×10^{-1}

(c) 1.3×10^{-6} (d) 1.3×10^{-8}

49. Calculate the pH of a solution containing 0.1 M HCO_3^- and 0.2 M CO_3^{2-} [$K_1(H_2CO_3) = 4.2 \times 10^{-7} \times 10$ and $K_2(HCO_3^-) = 4.8 \times 10^{-11}$].

(a) 3.18 (b) 10.62

(b) 6.62 (d) 9.31

50. Calculate the pH at which an acid indicator with K_{acid}(indicator) $= 1.0 \times 10^{-5}$ changes colour when the concentration of the indicator is 1×10^{-3} M.

(a) 5 (b) 11

(c) 3 (d) 8

51. At what pH will a 1×10^{-4} M solution of an indicator will K_b (indicator) $= 1 \times 10^{-11}$ change colour?

(a) 7.0 (b) 3.0

(c) 5.5 (d) 11.0

52. An acid-base indicator has a $K_a = 1.0 \times 10^{-5}$. The acid form of the indicator is red and the basic form is blue. Calculate the pH change required to change the colour of the indicator from 80% red to 80% blue.

(a) 1.20 (b) 0.80

(c) 0.20 (d) 1.40

53. Calculate the pH of a 0.01 M $NaHCO_3$ solution [$K_1(H_2CO_3) = 4 \times 10^{-7}$, $K_2(HCO_3^-) = 4.8 \times 10^{-11}$].

(a) 9.38 (b) 6.38 (c) 8.38 (d) 7.38

54. Which of the following statements is correct for glycine?

(a) It behaves as a base when titrated with HCl.

(b) It behaves as an acid when titrated with NaOH.

(c) It forms the zwitterion $\overset{+}{N}H_3CO_2COO^-$.

(d) All of these

55. The pH of glycine at the first half-equivalence point is 2.34 and that at the second half-equivalence point is 9.60. At the equivalence point (the first inflection point), the pH is

(a) 3.63 (b) 2.34
(c) 5.97 (d) 11.94

56. The pH at which a dipolar ion does not migrate from the anode to cathode in an electric field is called the

(a) isomeric point (b) isoelectric point
(c) inflection point (d) equivalence point

57. The pK_a' values for the $A \rightarrow B$, $B \rightarrow C$ and $C \rightarrow D$ dissociations are 2.09, 3.86 and 9.82 respectively. Since only B has an equal number of positive and negative charges, the value of the isoelectric point is

(a) 5.26 (b) 3.86
(c) 2.98 (d) 15.77

58. The effectiveness of a buffer is measured in terms of

(a) buffer action (b) buffer capacity
(c) hydrolysis constant (d) pK_a and pK_b

59. Buffer capacity is defined as the amount of acid or base that must be added to the buffer to cause

(a) one unit change of pH (b) two unit changes of pH
(c) no change in pH (d) the pH to equal $pK_a \pm 1$

60. Which of the following buffers has a pH range from 8.25 to 10.25?

(a) $Na_2CO_3/NaHCO_3$ (b) Na_3PO_4/Na_2HPO_4
(c) Na_2HPO_4/NaH_2PO_4 (d) sodium borate/boric acid

61. Which of the following does not indicate buffer action?

(a) $HA + HCO_3^- \rightleftharpoons A^- + H_2CO_3$
$B + H_2CO_3 \rightleftharpoons BH^+ + HCO_3^-$

(b) $HA + HPO_4^{2-} \rightleftharpoons A^- + H_2PO_4^-$
$B + H_2PO_4^- \rightleftharpoons BH^+ + HPO_4^{2-}$

(c) $HA + PO_4^{3-} \rightleftharpoons HPO_4^{2-} + A^-$
$B + HPO_4^{2-} \rightleftharpoons PO_4^{3-} + BH$

(d) $HA + CH_3COO^- \rightleftharpoons A^- + CH_3COOH$
$B + CH_3COOH \rightleftharpoons BH^+ + CH_3COO^-$

62. Blood plasma is maintained at a pH of 7.4 largely by the

(a) HCO_3^-/H_2CO_3 buffer

(b) HPO_4^{2-}/PO_4^{3-} buffer

(c) HCO_3^-/H_2CO_3 and $HPO_4^{2-}/H_2PO_4^-$ buffers

(d) HPO_4^{2-}/H_3PO_4 and haemoglobin buffers

63. The $[HCO_3^-]/[H_2CO_3]$ ratio in the blood (pH = 7.4) is approximately ($pK_a = 6.1$ for H_2CO_3)

(a) 20 (b) 16

(c) 24 (d) 10

64. In the titration of a weak diprotic acid (H_2A) with a strong base (NaOH), $[H^+]$ is given by

(a) $\sqrt{K_{a_1} c_a}$ (b) $K_a\sqrt{c_{a_1}}$

(c) $K_a c_{a_1}$ (d) K_{a_1}

(where K_a is the dissociation constant for the first stage and c_a is the concentration of the weak acid).

65. During the titration of a weak diprotic acid (H_2A) against a strong base (NaOH), the pH of the solution half-way to the first inflection point and that at the first inflection point are given respectively by

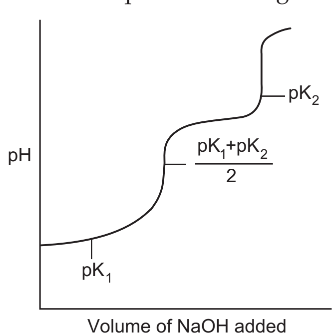
(a) pK_1 and $pK_1 + pK_2$ (b) $\sqrt{K_1 c_a}$ and $\dfrac{pK_1 + pK_2}{2}$

(c) pK_1 and $\dfrac{pK_1 + pK_2}{2}$ (d) $pK_1 + pK_w$ and $\dfrac{pK_1 + pK_2}{pK_w}$

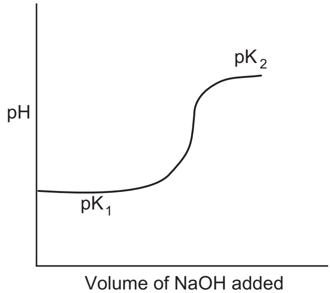
where K_1 and K_2 are the first and second dissociation constants of H_2A, and c_a is the initial concentration of the weak acid.

66. Which of the following curves indicates the titration of a weak diprotic acid by NaOH of equivalent strength?

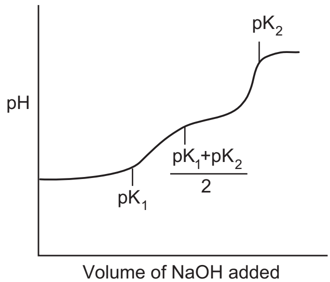
(a)



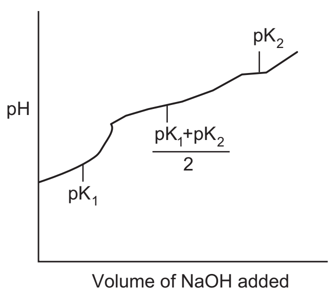
(b)



(c)



(d)



67. Which of the following represents hydrolysis?

(a) $HCO_3^- + H_2O \rightleftharpoons CO_3^{2-} + H_3O^+$

(b) $HCO_3^- + H_2O \rightleftharpoons H_2CO_3 + OH^-$

(c) $H_3BO_3 + H_2O \rightleftharpoons H_2BO_3^- + H_3O^+$

(d) $H_2PO_4^- + H_2O \rightleftharpoons HPO_4^{2-} + H_3O^+$

68. The concentration of a sample of H_2CO_3 is 1.0×10^{-3} M. Which of the following is correct?

(a) $1.0 \times 10^{-3}\,M = [H_2CO_3] + [HCO_3^-] + 2[CO_3^{2-}]$

(b) $1.0 \times 10^{-3}\,M = [H_2CO_3]$

(c) $1.0 \times 10^{-3}\,M = [H_2CO_3] + [HCO_3^-] + [CO_3^{2-}]$

(d) $1.0 \times 10^{-3}\,M = [H_2CO_3] + [HCO_3^-]$

69. The inflection point of a titration curve is the point at which

(a) the second derivative is zero (b) pH = 0
(c) pH = 7 (d) the first derivative is zero

• *Type 2* •

Choose the correct options. More than one option is correct.

70. Which of the following mixtures constitute a buffer?
(a) $CH_3COOH + CH_3COONa$ (b) $Na_2CO_3 + NaHCO_3$
(c) $NaCl + HCl$ (d) $NH_4Cl + (NH_4)_2SO_4$

71. Which of the following mixtures constitute a buffer?
(a) $Na_2CO_3 + HCl$ (b) $NaOH + CH_3COOH$
(c) $NH_3 + CH_3COONH_4$ (d) $NaOH + BaCl_2$

72. In which of the following pairs of solutions is there no effect on the pH upon dilution?
(a) 0.1 M NH_3 and 0.1 M $(NH_4)_2SO_4$
(b) 0.1 M NaH_2PO_4 and 0.1 M Na_2HPO_4
(c) 0.1 M HCl and 0.01 M NaOH
(d) 0.1 M KCl and 0.1 M HCl

73. Which of the following will suppress the ionization of phthalic acid in an aqueous solution?
(a) KCl (b) H_2SO (c) HNO_3 (d) NaOH

74. Which of the following buffers have a pH greater than 7?
(a) $NaHCO_3 + Na_2CO_3$ (b) $CH_3COOH + CH_3COONa$
(c) $Na_3PO_4 + NaH_2PO_4$ (d) $NH_3 + (NH_4)_2SO_4$

75. Which of the following mixtures can act as a buffer?
(a) $NaOH + CH_3COONa$ (1 : 1 molar ratio)
(b) $CH_3COOH + NaOH$ (2 : 1 molar ratio)
(c) $CH_3COOH + NaOH$ (3 : 1 molar ratio)
(d) $CH_3COOH + NaOH$ (1 : 1 molar ratio)

76. When HCl(g) is passed through a saturated solution of common salt, pure NaCl is precipitated because
(a) HCl is highly soluble in water
(b) the ionic product $[Na^+][Cl^-]$ exceeds its solubility product (K_{sp})
(c) the K_{sp} of NaCl is lowered by the presence of Cl^- ions
(d) HCl causes precipitation

Answers

1. c	**2.** b	**3.** a	**4.** d	**5.** a
6. a	**7.** d	**8.** b	**9.** a	**10.** c
11. a	**12.** b	**13.** d	**14.** c	**15.** b
16. a	**17.** b	**18.** d	**19.** c	**20.** b
21. d	**22.** c	**23.** d	**24.** b	**25.** a
26. c	**27.** b	**28.** b	**29.** a	**30.** c
31. d	**32.** b	**33.** d	**34.** a	**35.** a
36. d	**37.** b	**38.** c	**39.** c	**40.** a
41. b	**42.** c	**43.** d	**44.** b	**45.** c
46. b	**47.** a	**48.** c	**49.** b	**50.** a
51. b	**52.** a	**53.** c	**54.** d	**55.** c
56. b	**57.** c	**58.** b	**59.** a	**60.** d
61. c	**62.** c	**63.** a	**64.** a	**65.** c
66. a	**67.** b	**68.** c	**69.** a	**70.** a, b
71. a, b	**72.** a, b	**73.** b, c	**74.** a, b	**75.** b, c
76. b, d				

Hints to More Difficult Problems

2. $H^+ = \dfrac{(25 \times 0.3 - 25 \times 0.1)\text{ meq}}{100\text{ mL}} = 0.05\text{ M}.$

6. $HA + H_2O \rightleftharpoons H_3O^+ + A^-, \qquad K_a(HA) = \dfrac{[H_3O^+][A^-]}{[HA]}.$ (1)

$A^- + H_2O \rightleftharpoons OH^- + HA^-, \qquad K_b(A^-) = \dfrac{[OH^-][HA]}{[HA^-]}.$ (2)

Multiplying Equation (1) by Equation (2),

$$K_a(HA) \times K_b(A^-) = [H_3O^+][OH^-] = K_w.$$

7. The degree of dissociation increases with dilution.

8. $pH = \dfrac{1}{2}pK_a - \dfrac{1}{2}\log C = \dfrac{1}{2} \times 6 - \dfrac{1}{2}\log(0.01)$

$= 3 + 1 = 4.$

11. Glycine ($H_2N \cdot CH_2CO_2H$) contains an acidic group as well as a basic group.

15. Number of milliequivalents of HCl $= 2 \times 10^{-3}$.

We know that pH + pOH = 14

$\Rightarrow \quad 10 + pOH = 14.$

$pOH = 10^{-4}$ M.

3 mL of 10^{-4} M NaOH $\equiv 3 \times 10^{-4}$.

Number of milliequivalents of NaOH $= 3 \times 10^{-4}$.
The resulting solution is acidic.

$$[H^+] = \frac{(2 \times 10^{-3} - 3 \times 10^{-4} \text{ m. eq.}}{(2+3) \text{ mL}} = 3.4 \times 10^{-4} \text{ M}$$

or $\quad pH = -\log[H^+] = -\log(3.4 \times 10^{-4}) = 3.5.$

18. Use the Henderson equation

$$pH = pK_a + \log \frac{[OAC^-]}{[HOAC^-]}.$$

19. At the equivalence point, 0.10 M of HCOONa (sodium formate) is formed. This problem is solved by the considering the concept of hydrolysis equilibria.

$$pH = \frac{1}{2} pK_w + \frac{1}{2} pK_a + \frac{1}{2} \log C$$

$$= \frac{1}{2} \times 14 + \frac{1}{2} \times 3.74 + \frac{1}{2} \log 0.1 = 8.37.$$

26. $K_a \cdot K_b = K_w$
Under this condition,

$$pH = pK_a = 8 \Rightarrow K_a = 10^{-8}$$

or $\quad 10^{-8} \cdot K_b = 10^{-14} \Rightarrow K_b = 10^{-6}.$

29. K_{sp} for A_2B_3 equilibria $= 108 \, S^5 = 108 \times (1.0 \times 10^{-3})^5$
$= 1.08 \times 10^{-13}.$

34. The precipitation will occur when $Q > K_{sp}$.
$Q = 10^{-4} \times 10^{-4} = 10^{-8} > K_{sp}(1.8 \times 10^{-10})$.

38.
$$\underset{1 \times 10^{-3}\text{ mol}}{\underset{\downarrow}{Ag^+}} + \underset{5 \times 10^{-3}\text{ mol}}{\underset{\downarrow}{Cl^-}} \longrightarrow AgCl(s)$$

{[HCl] $= 50 \text{ mL} \times 0.1 \text{ mol L}^{-1}$
$= 5.0 \text{ m mol} = 5.0 \times 10^{-3}$ mol.
$[H^+] = [Cl^-] = 5.0 \times 10^{-3}$ mol}.
$[Cl^-] = 4 \times 10^{-3}$ mol after the reaction.

$$[Ag^+] = \frac{1.0 \times 10^{-10}}{4.0 \times 10^{-3}} = 2.5 \times 10^{-8}.$$

44. $[OH^-] = \dfrac{x \times 0.1 - x \times 0.05}{2x} = 2.5 \times 10^{-2}$.

$pOH = 2 - 0.4 = 1.6 \Rightarrow pH = 12.4$.

45. $pK_b = 10.83$, $\log K_b = -10.83 = \overline{11}.17$

$\Rightarrow \quad K_b = 1.479 \times 10^{-11}$.

$K_a \cdot K_b = K_w$

or $\quad K_a \times 1.479 \times 10^{-11} = 1.0 \times 10^{-14} \Rightarrow K_a = 6.76 \times 10^{-4}$.

48. The hydrolysis of $C_2O_4^{2-}$ is represented by

$$C_2O_4^{2-} + H_2O \rightleftharpoons HC_2O_4^- + OH^-$$

$$K_h = \frac{K_w}{K_2} = \frac{1.0 \times 10^{-14}}{6.1 \times 10^{-5}} = \frac{x^2}{0.01}.$$

$\therefore \quad x = 1.3 \times 10^{-6}$.

49. $HCO_3^- + H_2O \longrightarrow H_3O^+ + CO_3^{2-}$

$$K_2 = \frac{[H_3O^+][CO_3^{2-}]}{[HCO_3^-]} = 4.8 \times 10^{-11}.$$

$$[H_3O^+] = 4.8 \times 10^{-11} \times \frac{[HCO_3^-]}{[CO_3^{2-}]} = 4.8 \times 10^{-11}\left(\frac{0.1}{0.2}\right).$$

$$pH = -\log[H_3O^+] = -\log[4.8 \times 10^{-11} \times 0.5]$$

$$= 10.62.$$

50. Use the equation

$$pH = pK_{In} + \log\frac{[In^-]}{[HIn]}.$$

During change of colour, i.e., at the neutral point,

$$[In^-] = [HIn] \quad \text{or} \quad pH = pK_{In} = -\log(1.0 \times 10^{-5}).$$

$\therefore \quad pH = 5$

52. Consider an indicator of the type HIn which is ionized as

$$HIn \rightleftharpoons H^+ + In^-$$

According to the question, 20% of the final form of the indicator is blue (acidic) and 80% red (basic).

$K_{In} = \dfrac{[H^+][In^-]}{[HIn]}$, where K_{In} is the indicator constant.

$$[H^+] = K_{In}\frac{[In^-]}{[HIn]} = 1 \times 10^{-5}\left(\frac{80}{20}\right) = 4 \times 10^{-5}.$$

$pH = 4.4$.

For 80% blue, $[H^+] = 1 \times 10^{-5}\left(\frac{20}{80}\right)$.

$$pH = 6 - 0.4 = 5.6.$$

$$\Delta pH = 5.6 - 4.4 = 1.2.$$

57. The pH at which the dipolar ion does not migrate in an electric field is called the isoelectric point, denoted by pI.

The isoelectric point $pI = \frac{2.09 + 3.86}{2} = 2.975 \approx 2.98.$

60. $pK_a(H_3BO_3) = 9.25.$
$pH = pK_a \pm 1$, i.e., 8.25 and 10.25.

63. $pH = pK_a + \log\frac{[HCO_3^-]}{[H_2CO_3]}$

or $\quad 7.4 = 6.1 + \log\frac{[HCO_3^-]}{[H_2CO_3]}$

or $\quad \frac{[HCO_3^-]}{[H_2CO_3]} = 20.$

64. For $H_2A \rightleftharpoons H^+ + HA^-$,

$K_{a_1} = \frac{[H^+][HA^-]}{[H_2A]} \approx \frac{[H^+]^2}{c_a}$.

$\therefore \quad [H^+] = \sqrt{K_{a_1} c_a}.$

65. At this point, half of the H_2A has been converted to HA^- so that $[HA] \approx [H_2A]$, giving
$K_{a_1} = [H^+] \qquad pH = pK_1.$

68. Use the electroneutrality principle.

75. Both will give a mixture of CH_3COOH and CH_3COONa which serve as buffers.

❑

15

Electrochemistry

• *Type 1* •

Choose the correct option. Only one option is correct.

1. Which of the following aqueous solutions remains neutral after electrolysis?

(a) $CuSO_4$ (b) $AgNO_3$

(c) K_2SO_4 (d) $NaCl$

2. Which of the following aqueous solutions remains acidic after electrolysis?

(a) $K_2Cr_2O_7$ (b) $KMnO_4$

(c) CH_3COONa (d) $CuCl_2$

3. Which of the following statements is correct for a solid-state lithium battery?

(a) The electrolyte is made of a polymer material that permits the passage of electrons but not ions, and the battery is not rechargable.

(b) The electrolyte is made of a polymer material that permits the passage of ions but not electrons, and the battery is rechargable.

(c) The voltage of the battery can go up to 12 V.

(d) The anode is made of what is known as an insertion compound.

4. How many faradays are required to reduce 1 mol of BrO_3^- to Br^-?

(a) 3 (b) 5

(c) 6 (d) 4

5. How many moles of Zn^{2+} carry a charge of 2×10^{-5} C?

(a) 1×10^{-4} (b) 4×10^{-10}

(c) 4×10^{-5} (d) 1×10^{-10}

6. A steady current of 3.0 A for 1 hour corresponds to a passage of

(a) 1.08×10^5 C (b) 0.11 F

(c) 1.08×10^4 electrons (d) 1.51 V

7. How many kilojoules of energy is expended during the passage of a current of 0.1 A for 100 s under a potential of 150 V?

(a) 1.50 (b) 0.15

(c) 2.50 (d) 9.65

8. A metal wire carries a current of 1 A. How many electrons move past a point in the wire in one second?

(a) 6.02×10^{23} (b) 3.12×10^{18}

(c) 3.02×10^{23} (d) 6.24×10^{18}

9. In the electrolysis of aqueous NaCl, for how long would you have to pass a current of 1.0 A through the cell to convert 1.0 L of a 1 M NaCl solution into 1 M of NaOH?

(a) 35.5 hours (b) 23.8 hours

(c) 15.6 hours (d) 26.8 hours

10. How much charge is required to produce hydrogen gas at the rate of 1 mL s^{-1} by the electrolysis of molten NaCl?

(a) 8.6 C (b) 18.4 C

(c) 4.3 C (d) 1.4 C

11. The number of electrons gained and lost during the electrolysis of 35.5 g of Cl^- and 65.4 g of Zn^{2+} respectively are

(a) 3.01×10^{23} and 3.01×10^{23}

(b) 6.02×10^{23} and 3.01×10^{23}

(c) 6.02×10^{23} and 6.02×10^{23}

(d) 3.01×10^{23} and 6.02×10^{23}

12. Chromium metal can be plated out from an acidic solution containing CrO_3 according to the following equation (atomic weight of Cr = 52).

$$CrO_3(g) + 6H^+ + 6e \rightarrow Cr(s) + 3H_2O$$

How many grams of chromium will be plated by 22400 C?

(a) 2.96 (b) 2.16

(c) 21.6 (d) 23.2

13. A current of 0.250 A is passed through 400 mL of a 2.0 M solution of NaCl for 35 minutes. What will be the pH of the solution after the current is turned off?

(a) 12.98 (b) 12.13

(c) 10.48 (d) 9.24

14. After the electrolysis of a sodium chloride solution with inert electrodes for a certain period of time, 600 mL of a 1 N NaOH solution was left. During the same time 31.80 g Cu was deposited in a copper voltameter in series with the electrolytic cell. Calculate the percentage of NaOH obtained (atomic weight of Cu = 63.6).

(a) 40 (b) 50

(c) 60 (d) 25

15. During the purification of copper by electrolysis

(a) the anodes used are made of copper ore

(b) pure copper is deposited on the cathodes, with the evolution of hydrogen at the cathodes

(c) the impurities such as Ag, Au, Zn and Fe go into solution

(d) the voltage is carefully controlled to prevent the deposition of Zn and Fe at the cathode

16. The density of copper is 8.94 g mL^{-1}. Find the charge needed to plate an area of 10×10 cm^2 to a thickness of 10^{-2} cm using a $CuSO_4$ solution as electrolyte (atomic weight of Cu = 63.6).

(a) 2.7×10^4 C (b) 8.8×10^4 C

(c) 18.3×10^4 C (d) 1.7×10^4 C

17. Calculate the volume of gas liberated at the anode at stp during the electrolysis of a $CuSO_4$ solution by a current of 1 A passed for 16 minutes 5 seconds.

(a) 224 mL (b) 56 mL

(c) 112 mL (d) 448 mL

18. Acidified water was electrolysed using an inert electrode. The volume of gases liberated at stp was 168 mL. The amount of electricity passed through the acidified water was

(a) 96,500 C (b) 9,650 C

(c) 965 C (d) 168 C

19. For the cell reaction

$$2Hg(l) + 2Ag^+(aq) \rightarrow 2Ag(s) + Hg_2^{2+}(aq)$$

it is given that

$$E^0_{Ag^+/Ag} = 0.800\text{ V}, \ [Ag^+] = 10^{-3}\text{ M},$$

$$E^0_{Hg_2^{2+}/Hg} = 0.785\text{ V and } [Hg_2^{2+}] = 10^{-1}\text{ M}$$

(a) The forward reaction is spontaneous.

(b) The backward reaction is spontaneous.

(c) $E_{cell} = 1.585$ V

(d) $E_{cell} = 3.170$ V

20. Consider the cell reaction

$$Mg(s) + Cu^{2+}(aq) \rightarrow Cu(s) + Mg^{2+}(aq)$$

If the standard reduction potentials of $Mg^{2+}/Mg(s)$ and $Cu^{2+}/Cu(s)$ are -2.37 V and $+0.34$ V respectively, $E°$ for the cell is

(a) -2.71 V (b) $+2.71$ V

(c) -2.03 V (d) $+2.03$ V

21. If all species are in their standard states, which of the following is the strongest oxidizing agent?

(a) Br^- (b) Zn^{2+}

(c) Fe^{2+} (d) Co^{3+}

22. During the electrolysis of a concentrated brine solution, the amount of chlorine gas produced by the passage of 2F of electricity is

(a) 0.25 mol (b) 0.50 mol

(c) 1.00 mol (d) 2.00 mol

23. $Fe^{3+}(aq) + e \rightarrow Fe^{2+}; E^0 = +0.77$ V

$Al^{3+}(aq) + 3e \rightarrow Al(s); E^0 = -1.66$ V

$Br_2(aq) + 2e \rightarrow 2Br^-(aq); E^0 = +1.08$ V

Considering the above data, state which of the following represents the correct order of reducing power.

(a) $Br^- < Fe^{2+} < Al$ (b) $Fe^{2+} < Al < Br^-$

(c) $Al < Br^- < Fe^{2+}$ (d) $Al < Fe^{2+} < Br^-$

24. $E^0_{Na^+/Na(s)} = -2.71$ V,

$E^0_{Mg^{2+}/Mg(s)} = -2.37$ V,

$E^0_{Fe^{2+}/Fe(s)} = -0.44$ V and

$E^0_{Cr^{3+}/Cr(s)} = -0.41$ V.

Based on this data, state which of the following is the weakest reducing agent.

(a) Na^+ (b) Na

(c) Cr (d) Fe^{2+}

25. Given that $E^0_{Ag^+/Ag} = +0.80$ V and $E^0_{Zn^{2+}/Zn} = -0.76$ V, which of the following is correct?

(a) Ag^+ can be reduced by H_2.

(b) Ag can oxidize H_2 into H^+.

(c) Zn^{2+} can be reduced by H_2.

(d) Ag can reduce Zn^{2+}.

26. For the cell reaction

$$Cu^{2+}(aq)(c_1) + Zn(s) \rightarrow Zn^{2+}(aq)(c_2) + Cu(s)$$

the change in free energy ΔG at a given temperature is a function of

(a) $\ln c_1$ (b) $\ln (c_2/c_1)$

(c) $\ln (c_1 + c_2)$ (d) $\ln (c_2)$

27. A gas X at 1 atm is bubbled through a solution containing a mixture of 1 M Y^- and 1 M Z^- at 25°C. If the order of reduction potential is $Z > Y > X$,

(a) Y will oxidize X and not Z

(b) Y will oxidize Z and not X

(c) Y will oxidize X as well as Z

(d) Y will reduce as well as X and Z

28. The value of the reaction quotient, Q, for the cell

$$Zn(s) \mid Zn^{2+}(0.01\text{ M}) \parallel Ag^{+}(1.25\text{ M}) \mid Ag(s) \text{ is}$$

(a) 156 (b) 125

(c) 1.25×10^{-2} (d) 6.4×10^{-3}

29. The logarithm of the equilibrium constant, $\log K_{eq}$, of the net cell reaction of the cell, $X(s) \mid X^{2+} \parallel Y^{+} \mid Y(s)$ (given $E^0_{cell} = 1.20$ V), is

(a) 47.2 (b) 40.5

(c) 21.4 (d) 12.5

30. The temperature coefficient of a cell whose operation is based on the reaction $Pb(s) + HgCl_2(aq) \rightarrow PbCl_2(aq) + Hg(l)$ is

$$\left(\frac{\partial E}{\partial T}\right)_p = 1.5 \times 10^{-4}\text{ V K}^{-1}.$$

The amount of heat released during the operation is

(a) 8.4 kJ mol^{-1} (b) 16.4 kJ mol^{-1}

(c) 6.5 kJ mol^{-1} (d) 4.5 kJ mol^{-1}

31. Calculate the useful work done during the reaction

$$Ag(s) + \frac{1}{2}Cl_2(g) \rightarrow AgCl(s)$$

given that $E^0_{Cl_2/Cl^-} = +1.36$ V and $E^0_{AgCl,\,Ag,\,Cl^-} = +0.220$ V if $p_{Cl_2} = 1$ and $T = 298$ K.

(a) 110 kJ mol^{-1} (b) 220 kJ mol^{-1}

(c) 55 kJ mol^{-1} (d) 100 kJ mol^{-1}

32. Determine the electrode potential for

$$\begin{array}{c|l} \text{Pt, } H_2(g) & H^+(aq) \\ p_{H_2} = 1 \text{ atm} & a_{H^+} = 0.1 \end{array}$$

(a) 0 (b) 0.0592 V
(c) −0.0592 V (d) 0.1184 V

33. Calculate the equilibrium constant of the reaction

$$Cd^{2+}(aq) + Zn(s) \rightarrow Zn^{2+}(aq) + Cd(s)$$

if $E^0_{Cd^{2+}/Cd} = -0.403$ V and $E^0_{Zn^{2+}/Zn} = -0.763$ V.

(a) $K = 1.45 \times 10^{12}$ (b) $K = 4.25 \times 10^{14}$
(c) $K = 1.45 \times 10^{18}$ (d) $K = 14.4 \times 10^{11}$

34. Given that at 25°C,
for $Cr^{3+}(aq) + e \rightarrow Cr^{2+}(aq)$, $E^0 = -0.424$ V
$Cr^{2+}(aq) + 2e \rightarrow Cr(s)$, $E^0 = -0.900$ V
find E^0 at 25°C for $Cr^{3+}(aq) + 3e \rightarrow Cr(s)$.

(a) −0.74 V (b) +0.74 V (c) −1.324 V (d) −0.476 V

35. Calculate the emf of the following cell at 25°C.

$$Ag(s) \mid AgNO_3(0.01 \text{ mol kg}^{-1}) \parallel AgNO_3(0.05 \text{ mol kg}^{-1}) \mid Ag(s)$$

(a) −0.414 V (b) 0.828 V
(c) 0.414 V (d) 0.0414 V

36. Consider the given data.

Half-cell reaction	Standard reduction potential, E^0 (volts)
1. $Cr_2O_7^{2-} + 14H^+ + 6e \rightleftharpoons 2Cr^{3+} + 7H_2O$	1.33
2. $Cr^{3+} + 3e \rightleftharpoons Cr(s)$	−0.74
3. $Cu^+ + e \rightleftharpoons Cu(s)$	0.52
4. $Cu^{2+} + 2e \rightleftharpoons Cu(s)$	0.34

The numerical value of the standard cell potential for the reaction

$$2Cr^{3+} + 3Cu^{2+}(aq) \rightleftharpoons 2Cr^{3+}(aq) + 3Cu(s)$$

is

(a) −1.08 V (b) −0.40 V (c) 1.08 V (d) 0.34 V

37. For the electrochemical cell

$$\overset{\ominus}{Ag} \mid AgCl(s), KCl(aq) \parallel AgNO_3(aq) \mid \overset{\oplus}{Ag}$$

the overall cell reaction is

(a) $Ag^+ + KCl(aq) \longrightarrow AgCl(s) + K^+$
(b) $Ag(s) + AgCl(s) \longrightarrow 2Ag(s) + \frac{1}{2}Cl_2(g)$

(c) $AgCl(s) \longrightarrow Ag^+ + Cl^-$

(d) $Ag^+ + Cl^- \longrightarrow AgCl(s)$

38. When $\Delta G = -100$ kJ mol^{-1} and $n = 1$, the potential of the cell is

(a) 2 V (b) 1 V (c) 10 V (d) 5 V

39. Given the half-cell reactions

(i) $Fe^{2+}(aq) + 2e \longrightarrow Fe(s)$; $E^0 = -0.44$ V

(ii) $2H^+(aq) + \frac{1}{2}O_2(g) + 2e \longrightarrow H_2O(l)$; $E^0 = +1.23$ V

E^0 for the reaction

$$Fe(s) + 2H^+ + \frac{1}{2}O_2(g) \longrightarrow Fe^{2+}(aq) + H_2O(l)$$

is

(a) +1.67 V (b) −1.67 V (c) −0.77 V (d) +0.77 V

40. Given the half-cell reactions

$$Cu^+(aq) + e \longrightarrow Cu(s), \quad E^0 = +0.52 \text{ V}$$
$$Cu^{2+}(aq) + e \longrightarrow Cu^+(aq), \quad E^0 = +0.16 \text{ V}$$

the equilibrium constant for the disproportionation reaction
$2Cu^+(aq) \longrightarrow Cu(s) + Cu^{2+}(aq)$ at 298 K is

(a) 6×10^4 (b) 6×10^6

(c) 1.2×10^6 (d) 1.2×10^{-6}

41. Which of the following statements are incorrect for an electrode concentration cell?

(a) The emf is usually small.

(b) The emf of the cell decreases continually during its operation as the concentrations in the two compartments approach each other.

(c) When the concentrations of the ions in the two compartments are the same, E(emf of cell) becomes zero.

(d) When the concentrations of the ions in the two compartments are the same, E^0 of the cell becomes zero.

42. Which of the following statements is incorrect?

(a) E^0 changes sign whenever a half-cell reaction is reversed.

(b) Changing the stoichiometric coefficients of a half-cell reaction does not affect the value of E^0 because electrode potential is an intensive property.

(c) The half-cell reactions are reversible.

(d) Changing the stoichiometric coefficients of a half-cell reaction does affect the value of E^0 because electrode potential is an extensive property.

43. The following concentration cell is a step-up cell.

$Zn(s) \mid Zn^{2+}(aq, 0.20\ M) \mid KCl(sat'd) \mid Zn^{2+}(aq, 2.0\ M) \mid Zn(s)$

Choose the correct option.

(a) Zn^{2+} reacts with Cl^- to form $ZnCl_2$.

(b) Zn(s) reacts with K(s) to form an intermetallic compound.

(c) Reduction occurs in the more concentrated compartment and oxidation takes place in the more dilute, according to Le Chatelier's principles

(d) Oxidation takes place in the more concentrated compartment and reduction in the more dilute, following Le Chatelier's principles.

44. A quantity of 0.300 g of Cu was deposited from a $CuSO_4$ solution by passing a current of 3.00 A through it for 304 s. The value of the faraday constant is

(a) 9.66×10^4 C (b) 9.66×10^3 C

(c) 9.66×10^5 C (d) 9.66×10^2 C

45. A solution containing H^+ and D^+ ions is in equilibrium with a mixture of H_2 and D_2 gases at 25°C. If the partial pressures of both the gases are 1.0 atm, calculate the ratio

$$[D^+]/[H^+] \quad (E^0_{D^+/D} = -0.003\ V).$$

(a) 1.2 (b) 1.1

(c) 0.11 (d) 1.0

46. A galvanic cell is constructed as follows. A half-cell consists of a platinum wire immersed in a solution containing 1.0 M of Sn^+ and 1.0 M of Sn^{4+}, and another half-cell has a thallium rod immersed in a 1.0 M solution of Tl^+.

Given $Sn^{4+}(aq) + 2e \longrightarrow Sn^{2+}(aq)$; $E^0 = +0.13$ V

and $Tl^{4+}(aq) + e \longrightarrow Tl(s)$; $E^0 = -0.34$ V,

what is the cell voltage if the Tl^+ concentration is increased tenfold?

(a) 0.411 V (b) 4.101 V (c) 0.492 V (d) 0.222 V

47. The cell formed by the two-redox couple ox_1/red_1 and ox_2/red_2 may be denoted by

$$red_1, ox_1 \parallel red_2, ox_2.$$

The cell reaction is

(a) $red_1 + ox_1 \longrightarrow red_2 + ox_2$ (b) $red_2 + ox_2 \longrightarrow red_1 + ox_1$

(c) $red_1 + ox_2 \longrightarrow ox_1 + red_2$ (d) $red_1 + red_2 \longrightarrow ox_1 + ox_2$

48. Given the cell reactions

$AgCl(s) + e \longrightarrow Ag(s) + Cl^-(aq)$; $E^0 = +0.22$ V

and $Ag^+(aq) + e \longrightarrow Ag(s)$; $E^0 = +0.80$ V

the solubility product of AgCl(s) at 298 K is

(a) 1.6×10^{-18} (b) 1.6×10^{-5}
(c) 1.6×10^{-12} (d) 1.6×10^{-10}

49. For the half-cell reaction

$$H^+(aq) + e \longrightarrow \frac{1}{2} \underset{1\ \text{atm}}{H_2(g)}$$

(a) $E(H^+/H_2) = -59.2\ \text{mV} \times \text{pH}$

(b) $E^0(H^+/H_2) = -59.2\ \text{mV} \times \text{pH}$

(c) $E^0(H^+/H_2) = \text{pH} \log[H^+]$

(d) $E(H^+/H_2) = -\text{pH} \log[H^+]$

50. In an H_2-O_2 fuel cell,

(a) the cell reaction is $2H_2O(l) \longrightarrow 2H_2(g) + O_2(g)$
(b) the cell reaction is $2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$
(c) the cell voltage is 2.0 V
(d) chemical energy is stored

51. The unit of ionic mobility is

(a) $m^{-2}V^{-1}s^{-1}$ (b) $m^2V^{-1}s^{-1}$
(c) $m^{-2}V\,s^{-1}$ (d) $m^2V^{-2}s^{-1}$

52. Drift speed of an ion is directly proportional to

(a) the strength of the applied field
(b) the strength of the applied field and the charge on the ion
(c) the strength of the applied field, the viscosity and the charge on the ion
(d) the cell constant of the conductivity cell

53. Which of the following statements is incorrect?

(a) Specific conductance of an electrolytic solution decreases with dilution
(b) Conductance of an electrolytic solution increases with dilution
(c) Equivalent conductance of an electrolytic solution increases with dilution
(d) Conductance of an electrolytic solution decreases with dilution

54. Which of the following compounds shows maximum value of equivalent conductance in a fused state?

(a) $MgCl_2$ (b) $BeCl_2$ (c) $CaCl_2$ (d) $SrCl_2$

55. Kohlrausch given the following relation for strong electrolyte

$$\Lambda = \Lambda_0 - B\sqrt{C}.$$

Which of the following equality holds?

(a) $\Lambda = \Lambda_0$ as $c \to 1$
(b) $\Lambda = \Lambda_0$ as $c \to 0$
(c) $\Lambda = \Lambda_0$ as $c \to \infty$
(d) $\Lambda = \Lambda_0$ as $c \to \sqrt{B}$

56. Which of the following statements is incorrect?

(a) There is no corelation between ionic size and conductance.
(b) Ions of normal fatty acids and ionic conductance attain a constant value.
(c) The ionic conductivity at infinite dilution is the highest for H^+ ion.
(d) The ionic conductivity of OH^- ion at infinite dilution is greater than that of H^+ ion.

57. The ionic conductance at an infinite dilution is related to

(a) the speed of the ions which move under the influence of an applied potential gradient
(b) the conductance ratio and the concentration of the solution
(c) equivalent and molar conductance
(d) weak van der Waals forces

58. Which of the following is arranged in order of increasing ionic conducrtance?

(a) $NH_4^+ < Ag^+ < Na^+ < Li^+$
(b) $Na^+ < NH_4^+ < Ag^+ < Li^+$
(c) $Li^+ < Na^+ < Ag^+ < NH_4^+$
(d) $Ag^+ < Li^+ < Na^+ < NH_4^+$

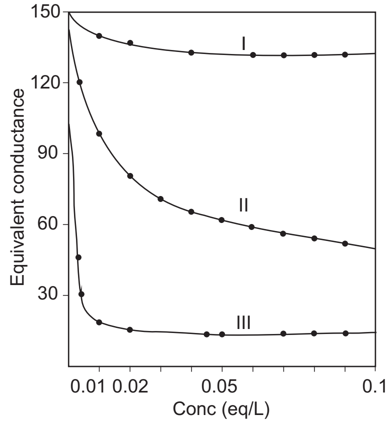
59. Which of the following compounds of 0.1 N concentration has smallest Λ_0?

(a) NaCl
(b) $NiSO_4$
(c) $CaCl_2$
(d) Na_2SO_4

60. If ρ is the resistance in ohm of a centimeter cube, generally called the specific resistance of the substance constituting the conductor, the resistance r of the layer containing "a" cubes is given by

(a) $\frac{1}{r} = \frac{1}{\rho} + \frac{1}{\rho} + \ldots$
(b) $\frac{1}{r} = \frac{1}{\rho a} + \frac{1}{\rho a} + \ldots$
(c) $r = a/\rho$
(d) $r = \rho + \rho + \ldots$

61. A graph was plotted between the equivalent conductance of various electrolytes (CH_3COOH, $NiSO_4$ and HCl) and their concentrations in equivalents per litre.



which of the followings represents the correct setting?

(a) I ($NiSO_4$), II (CH_3COOH), III (HCl)

(b) I (HCl), II ($NiSO_4$), III (CH_3COOH)

(c) I (CH_3COOH), II (HCl), III ($NiSO_4$)

(d) I (HCl), II (CH_3COOH), III ($NiSO_4$)

62. Which of the following statements is incorrect?

(a) Increase in temperature increases the equivalent conductance.

(b) Conductance ratio decreases with increase in temperature.

(c) The solvent with low dielectric constant and the equivalent conductance decrease with increase in concentration.

(d) The solvent with high dielectric constant and the equivalent conductance decrease with increase in concentration.

63. The expression $\alpha = \Lambda/\Lambda_0$ will not hold good for the electrolyte

(a) HOCN (b) H_2SO_4

(c) CH_3CH_2OH (d) CH_3CO_2H

64. The mathematical expression for law of independent migration of ions and Ostwald's dilution law are given by

(a) $\Lambda = \Lambda_m^0 - BC^{1/2}$ (b) $\Lambda_0 = F(U_+ + U_-)$

(c) $\Lambda_m^0 = \nu_+ \lambda_+ + \nu_- \lambda_1$ (d) $\dfrac{\Lambda_0}{\Lambda_m} = \dfrac{1}{\Lambda_m^0} + \dfrac{\Lambda_m c}{K_a(\Lambda_m^0)^2}$

65. The conductance of a solution of an electrolyte is equal to that of its specific conductance. The cell constant of the conductivity cell is equal to

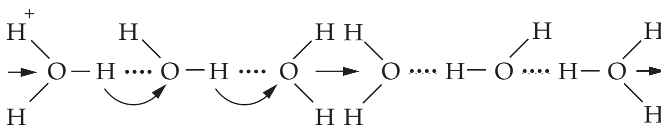
(a) resistance (b) faraday

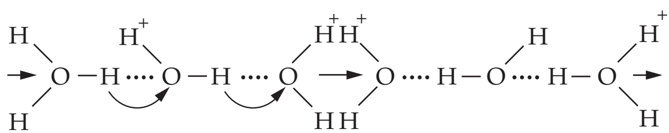
(c) zero (d) unity

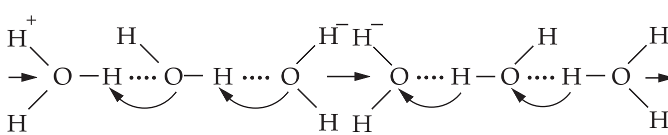
66. The equivalent conductance of an acetic acid solution of concentration 0.01 M is 1.65 m S m^2 mol^{-1} at 298 K. The dissociation constant of acetic acid at this temperature is (given, $\Lambda_0 = 39.0$ m S m^2 mol^{-1})

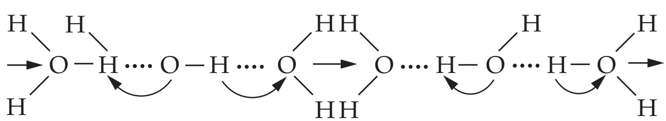
(a) 1.8×10^{-4} (b) 4.0×10^{-10} (c) 1.8×10^{-5} (d) 1.8×10^{-6}

67. The ionic mobility of H^+ ions are much higher than the other ions. These high values are the results of hydrogen bonding. In water, the proton is hydrated and its movement can be represented as

(a) 

(b) 

(c) 

(d) 

68. In the equation $\Lambda = \Lambda_m^0 - Bc^{1/2}$, the constant B depends upon

(a) $c^{1/2}$ (b) stoichiometry of the electrolyte
(c) resistance (d) specific conductivity

69. Which of the following is arranged in increasing order of ionic mobility?

(a) $I^- < Br^- < Cl^- < F^-$ (b) $F^- < Cl^- < Br^- < I^-$
(c) $F^- < I^- < Cl^- < Br^-$ (d) $F^- < Cl^- < I^- < Br^-$

70. Ionic mobility principle (utilized for purifying and identifying proteins) is based on

(a) electroosmosis (b) electrophoresis
(c) electrolysis (d) isoelectronic point

71. If the voltage across the electrode is 1 V, then $c(\lambda_0^+ + \lambda_0^-)$ represents the

(a) current (b) molar conductance
(c) conductance (d) ionic mobility

72. The specific conductance (κ) is given by

(a) $(\lambda_0^+ + \lambda_0^-)$ (b) $Vc(\lambda_0^+ + \lambda_0^-)$

(c) $c(\lambda_0^+ + \lambda_0^-)$ (d) $F(u_+ + u_-)$

73. The specific conductance of a saturated AgCl solution is found to be 1.86×10^{-6} S cm^{-1} and that for water is 6.0×10^{-8} S cm^{-1}. The solubility of AgCl is ($\Lambda_0 = 137.2$ S equiv^{-1} cm^2)

(a) 1.7×10^{-3} mol L^{-1} (b) 1.3×10^{-5} mol L^{-1}

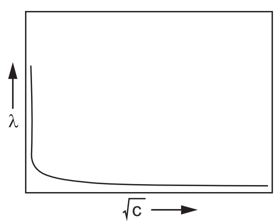
(c) 1.3×10^{-4} mol L^{-1} (d) 1.3×10^{-6} mol L^{-1}

74. Which of the following solutions of KCl will have the highest value of specific conductance?

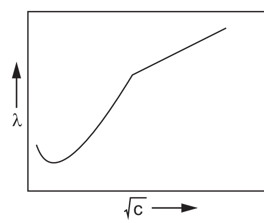
(a) 0.01 M (b) 0.1 M (c) 1.0 M (d) 0.5 M

75. The variation of equivalent conductance of a weak electrolyte with (concentration)$^{1/2}$ is represented as

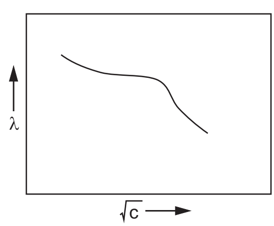
(a)



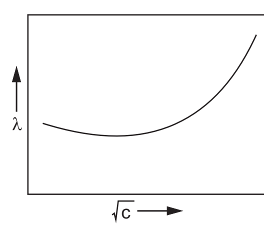
(b)



(c)



(d)



76. The equivalent conductance of strong electrolyte increases with dilution because of

(a) intermolecular interaction between the ions

(b) increase in number of ions per unit volume

(c) increase in degree of dissociation

(d) lower enthalpy of hydration

77. The ionic mobility of ions at infinite dilution is related to ionic conductance by

(a) $\Lambda_0 = F\kappa$ (b) $\Lambda_0 F = U_+ + U_-$

(c) $\Lambda_0 = U_+ + U_-$ (d) $\Lambda_0 = F(U_+ + U_-)$

78. The increase in equivalent conductance of a weak electrolyte with dilution is due to

(a) increase in degree of dissociation and decrease in ionic mobility

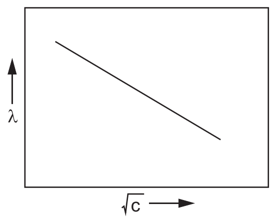
(b) decrease in degree of dissociation and decrease in ionic mobility

(c) increase in degree of dissociatin and increase in ionic mobility

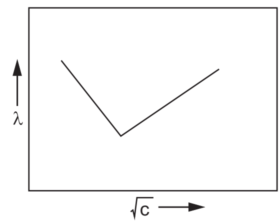
(d) decrease in degree of dissociation and increase in ionic mobility

79. The variation of equivalent conductance of strong electrolyte with (concentration)$^{1/2}$ is represented by

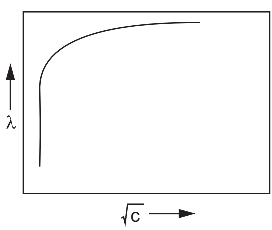
(a)



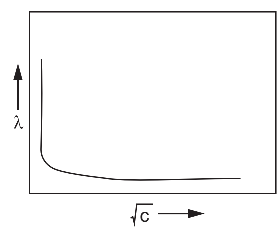
(b)



(c)



(d)



80. The relation among conductance (κ), specific conductance (*G*) and cell constant (*l*/*A*) is

(a) $G = \kappa \dfrac{l}{A}$ (b) $G = \kappa \dfrac{A}{l}$ (c) $G\kappa = \dfrac{l}{A}$ (d) $G = \kappa Al$

81. During conductivity measurement (based on Wheatstone bridge principle) using conductivity cell, alternating current (AC) is used because a direct current would lead to

(a) association and ionization

(b) electrolysis and polarization

(c) polymerization and polarization

(d) polarization

82. During conductivity measurement we use platinized platinum electrodes which

(a) catalyze the union of hydrogen and oxygen which tend to be liberated by the successive pulses of the current

(b) eliminates the polarization of emf

(c) both (a) and (b)

(d) none of these

83. The value of molar conductance of HCl is greater than that of NaCl at a given temperature and concentration because

(a) ionic mobility of HCl is greater than that of NaCl

(b) the dipole moment of NaCl is greater than that of HCl

(c) NaCl is more ionic than HCl

(d) HCl is Bronsted acid and NaCl is a salt of a strong acid and strong base

84. Which of the following statements is correct?

(a) The conductivity of a solution decreases with increasing viscosity and ion size.

(b) Molar conductivities of the alkali metal ions decrease from Li^+ to Cs^+

(c) Stokes formula is given by $f = 6\pi\eta Ga$

(d) According to the Grotthuss mechanism, there is an effective motion of a proton and neutron that involves the rearrangement of bonds in a group of water moelcules.

85. Aniline hydrochloride ($C_6H_5NH_3Cl$) is a salt of a weak base and strong acid. The hydrolysis equilibria

$$K_h = \frac{h^2c}{(1-h)}.$$

On the basis of conductivity, h is given by

(a) $h = \dfrac{\Lambda - \Lambda_1}{\Lambda_2 - \Lambda}$ (b) $h = \dfrac{\Lambda - \Lambda_1}{\Lambda_2 - \Lambda_1}$

(c) $h = \dfrac{\Lambda_2 + \Lambda_1}{\Lambda}$ (d) $h = \dfrac{\Lambda + \Lambda_1}{\Lambda_2 - \Lambda_1}$

Where $\Lambda, \Lambda_1, \Lambda_2$ are equivalent conductance of hydrolysed salt, unhydrolysed salt and HCl respectively, K_h = hydrolysis constant, c = concentration of $C_6H_5NH_3Cl$ and h = degree of hydrolysis.

• Type 2 •

Choose the correct options. More than one option is correct.

86. Which of the following statements is correct for ionic mobility?

(a) It depends upon the voltage across the electrodes.

(b) Lower the voltage, higher is the velocity.

(c) Ionic velocity per unit electric field strength is constant.

(d) All of these.

87. Which of the following units is correctly matched?

(a) SI units of conductivity (k) $\rightarrow$ siemens per metre ($S\ m^{-1}$)

(b) SI units of molar conductivity $\rightarrow$ siemens squared per mol ($S\ m^2\ mol^{-1}$)

(c) SI unit of ionic mobility $\rightarrow$ $m\ V^{-1}s^{-1}$

(d) All of these

88. According to Grotthuss model

(a) there is no coordinated motion of a proton along a chain of water molecules.

(b) there is a rapid hopping between neighbouring sites of water molecules.

(c) the system $H^+(H_2O)_4$ has low activation energy

(d) none of these

89. Oxygen and hydrogen gas are produced at the anode and cathode during the electrolysis of dilute aqueous solutions of

(a) Na_2SO_4 (b) $AgNO_3$

(c) H_2SO_4 (d) $NaOH$

90. Which of the following statements are correct?

(a) The electrolysis of aqueous NaCl produces hydrogen gas at the cathode and chlorine gas at the anode.

(b) The electrolysis of a dilute solution of sodium fluoride produces oxygen gas at the anode and hydrogen gas at the cathode.

(c) The electrolysis of concentrated sulphuric acid produces SO_2 gas at the anode and O_2 gas at the cathode.

(d) After the electrolysis of aqueous sodium sulphate, the solution becomes acidic.

91. Which of the following cell reactions correctly represent the electrolysis of water?

(a) $2H^+ + 2e \rightarrow H_2(g)$ (b) $2H_2O + 2e \rightarrow H_2(g) + 2(OH^-)$

(c) $4(OH^-) \rightarrow 2H_2O + O_2(g) + 4e$ (d) $2H_2O \rightarrow O_2(g) + 4H^+ + 4e$

92. Which of the following statements are correct?

(a) The electrolysis of concentrated H_2SO_4 at 0–5°C using a Pt electrode produces $H_2S_2O_8$.

(b) The electrolysis of a brine solution produces $NaClO_3$ and $NaClO$.

(c) The electrolysis of a $CuSO_4$ solution using Pt electrodes causes the liberation of O_2 at the anode and the deposition of copper at the cathode.

(d) All electrolytic reactions are redox reactions.

93. How much charge must be supplied to a cell for the electrolytic production of 245 g $NaClO_4$ from $NaClO_3$? Because of a side reaction, the anode efficiency for the desired reaction is 60%.

(a) 6.43×10^5 C
(b) 6.67 F
(c) 6.43×10^6 C
(d) 66.67 F

94. In an electrochemical process, a salt bridge is used

(a) to maintain electroneutrality in each solution
(b) to complete the circuit so that current can flow
(c) as an oxidizing agent
(d) as a colour indicator

95. Consider the cell

$$Cd(s) \mid Cd^{2+}(1.0\text{ M}) \parallel Cu^{2+}(1.0\text{ M}) \mid Cu(s)$$

If we wish to make a cell with a more positive voltage using the same substances, we should

(a) increase $[Cd^{2+}]$ as well as $[Cu^{2+}]$ to 2.0 M
(b) reduce only $[Cd^{2+}]$ to 0.1 M
(c) increase only $[Cu^{2+}]$ to 2.0 M
(d) decrease $[Cd^{2+}]$ as well as $[Cu^{2+}]$ to 0.1 M

96. A concentration cell is a galvanic cell in which

(a) the electrode material and the solutions in both half-cells are composed of the same substances
(b) only the concentrations of the two solutions differ
(c) $\Delta E^0_{\text{cell}} = 0$
(d) the Nernst equation reduces to $\Delta E_{\text{cell}} = -\left(\frac{0.0592}{n}\right) \log Q$ at 25°C

97. Which of the following statements are correct?

(a) A reaction is spontaneous from left to right if $K_{eq} > Q$, in which case $\Delta E_{\text{cell}} > 0$.
(b) A reaction occurs from right to left if $K_{eq} < Q$, in which case $\Delta E_{\text{cell}} < 0$.
(c) If the system is at equilibrium, no net reaction occurs.
(d) ΔE_{cell} is temperature-independent.

98. Which of the following are concentration cells?

(a) $\text{Pt}, \underset{p_1}{H_2(g)} \mid \underset{(m)}{HCl} \mid \underset{p_2}{H_2(g)}, \text{Pt}$
(b) $\text{Cd}, \underset{a_1}{(Hg)} \mid \underset{(m)}{Cd^{2+}} \mid \underset{a_2}{(Hg)}, \text{Cd}$

(c) $Zn(s)\,|\,\underset{m_1}{Zn^{2+}}\,||\,\underset{m_2}{Cu^{2+}}\,|\,Cu$

(d) $Ag(s), AgCl(s)\,|\,\underset{m}{HCl}\,||\,\underset{m}{HCl}\,|\,AgCl(s), Ag(s)$

99. $Pb(s)\,|\,\underset{\text{saturated solution}}{PbSO_4}\,||\,\underset{\text{saturated solution}}{PbI_2}\,|\,Pb(s)$

Which of the following expressions represent the emf of the above cell at 25°C?

(a) $E = \dfrac{0.0592}{2}\log\dfrac{(a_{Pb^{2+}})_2}{(a_{Pb^{2+}})_1}$

(b) $E = \dfrac{0.0592}{2}\log\dfrac{(a_{Pb^{2+}})_1}{(a_{Pb^{2+}})_2}$

(c) $E = \dfrac{0.0592}{2}\log\dfrac{[K_{sp}(PbI_2)]^{1/3}}{[K_{sp}(PbSO_4)]^{1/2}}$

(d) $E = \dfrac{0.0592}{2}\log\dfrac{K_{sp}(PbI_2)}{K_{sp}(PbSO_4)}$

100. Which of the following represent electrodes of the second kind?

(a) $Ag(s)\,|\,AgCl(s), Cl^-$

(b) $Cu(s)\,|\,CuSO_4(aq), SO_4^{2-}$

(c) $Hg(l)\,|\,Hg_2Cl_2(s), Cl^-$

(d) $Pb(s)\,|\,PbSO_4(s), SO_4^{2-}$

Answers

1. c	**2.** d	**3.** b	**4.** c	**5.** d
6. b	**7.** a	**8.** d	**9.** d	**10.** a
11. a	**12.** b	**13.** b	**14.** c	**15.** d
16. a	**17.** b	**18.** c	**19.** c	**20.** b
21. d	**22.** c	**23.** a	**24.** a	**25.** a
26. b	**27.** a	**28.** d	**29.** b	**30.** c
31. a	**32.** c	**33.** a	**34.** a	**35.** a
36. c	**37.** d	**38.** b	**39.** a	**40.** c
41. c	**42.** d	**43.** c	**44.** a	**45.** b
46. a	**47.** c	**48.** d	**49.** a	**50.** b
51. b	**52.** a	**53.** d	**54.** b	**55.** b
56. d	**57.** a	**58.** c	**59.** b	**60.** a
61. b	**62.** d	**63.** b	**64.** c	**65.** d

66. c	**67.** a	**68.** b	**69.** d	**70.** b
71. a	**72.** c	**73.** b	**74.** c	**75.** a
76. b	**77.** d	**78.** c	**79.** a	**80.** b
81. b	**82.** c	**83.** a	**84.** a	**85.** b
86. a, c	**87.** a, b	**88.** a, b, c	**89.** a, b, c, d	**90.** a, b
91. b, c	**92.** a, b, c, d	**93.** a, b	**94.** a, b	**95.** b, c
96. a, b, c, d	**97.** a, b, c	**98.** a, b, d	**99.** a, c	**100.** a, c, d

Hints to More Difficult Problems

1. K_2SO_4 is a salt of a strong acid and strong base. So the electrolysis of K_2SO_4(aq) is the electrolysis of water.

4. $BrO_3^- + 6H^+ + 6e \longrightarrow Br^- + 3H_2O$

7. Energy $= 0.1 \times 150 \times 100$ J $= 1.5$ kJ.

10. 1 equivalent $= 11200$ mL mol$^{-2} \equiv 1$ F mol$^{-1} = 96500$ C mol^{-1}.

As we know $Q = nF$ where n = no. of moles.

$$Q = \frac{1 \text{ mL}}{11200 \text{ mL mol}^{-1}} \times 96500 \text{ C mol}^{-1}$$

$$= 8.6 \text{ C.}$$

13. After electrolysis aqueous NaCl is converted into aqueous NaOH.

The quantity of electricity passed

$$= \frac{0.250 \times 35 \times 60}{96500 \text{ C}} \text{ A s} = 5.44 \times 10^{-3} \text{ F}$$

The number of equivalents of OH^- ion formed

$$= 5.44 \times 10^{-3}.$$

$$\therefore \quad \text{Molarity of NaOH} = \frac{5.44 \times 10^{-3}}{0.400 \text{ L}} \text{ eq.}$$

$$= 1.36 \times 10^{-2}.$$

pOH $= -\log(1.36 \times 10^{-2}) = 2.00 - 0.13 = 1.87$.

$\therefore$ pH $= 12.13$.

16. $W = \dfrac{A}{nF} It \quad$ or $\quad \rho \times V = \dfrac{A}{nF} Q.$

$$Q = \frac{\rho \times \text{area} \times \text{thickness}}{A} \times nF$$

$$= \frac{8.94 \times 10 \times 10 \times 10^{-2} \times 2 \times 96500}{63.6} = 2.7 \times 10^4 \text{ C.}$$

18. $2H_2O \longrightarrow \underset{2x}{2H_2(g)} + \underset{x}{O_2(g)}$

$3x = 168.$

$x = 56$ mL.

$V_{H_2} = 2x = 112$ mL.

$V_{O_2} = x = 56$ mL.

11200 mL of H_2 at stp $\equiv$ 1 F.

112 mL of H_2 at stp $\equiv$ 0.01 F.

5600 mL of O_2 at stp $\equiv$ 1 F.

56 mL of O_2 at stp $\equiv$ 0.01 F.

Amount of electricity passed = 0.01 F = $0.01 \times 96500 = 965$ C.

We get identical results whether we consider H_2 or O_2.

20. The cell is represented as

$$\overset{-}{\text{Mg}}(s) \mid Mg^{2+} \parallel Cu^{2+} \mid \overset{+}{\text{Cu}}(s)$$

$E^0 = E^0_{Cu^{2+} \mid Cu} - E^0_{Mg^{2+} \mid Mg}$

$= 0.34 - (-2.37) = 2.71$ V.

28. The cell reaction is

$$Zn(s) \longrightarrow Zn^{2+}(0.01)\ M$$

$$[Ag^+(1.25\ M) + e \longrightarrow Ag(s)] \times 2$$

$$Zn(s) + 2Ag^+(1.25)\ M \rightarrow Zn^{2+}(0.01\ M) + 2Ag(s)$$

$$Q = \frac{[Zn^{2+}]}{[Ag^+]^2} = \frac{0.01}{(1.25)^2} = 6.4 \times 10^{-3}.$$

29. $\Delta G^0 = -nE^0F = -RT \ln K_{eq}$

$$\Rightarrow \quad \ln K_{eq} = \frac{nE^0F}{RT} = \frac{nE^0}{RT/F}.$$

$$\log K_{eq} = \frac{nE^0}{2.303\dfrac{RT}{F}} = \frac{nE^0}{0.0592} \quad \text{(at 25°C)}$$

$$= \frac{2 \times 1.20}{0.0592} = 40.5.$$

31. For the cell reaction

$$Ag(s) + \frac{1}{2}Cl_2(g) \longrightarrow AgCl(s)$$

$E^0 = -1.14$ V

or $\quad E = E^0 - \dfrac{0.0592}{1} \log\, [Cl_2]^{1/2}.$

In standard conditions, $p_{Cl_2} = 1.$

$\therefore \quad \log[Cl_2]^{1/2} = 0.$

Useful work $= -W_{max} = \Delta G = -nEF$

$$= (-1) \times (-1.14) \times 96500 \times 10^{-3}\ \text{kJ mol}^{-1}$$

$$= 110\ \text{kJ mol}^{-1}.$$

34. Adding the first two reactions, we get the third equation and using the free-energy concept, we have

$$\Delta G_1^0 + \Delta G_2^0 = \Delta G_3^0 \quad (n = \text{no. of electrons involved}).$$

$$-n_1E_1^0F - n_2E_2^0F = -n_3E_3^0F.$$

$$E_3^0 = \frac{n_1E_1^0 + n_2E_2^0}{n_3} = \frac{1 \times (-0.424) + 2 \times (-0.900)}{3}$$

$$= -0.741\ \text{V}.$$

35. It is a concentration cell. The emf of a concentration cell is

$$E = +0.0592 \log \frac{C_1}{C_2} \text{ at } 25°\text{C and } n = 1$$

$$= +0.0592 \log \frac{0.01}{0.05} = -0.414\ \text{V}.$$

39. Equation (ii) – equation (i) = 1.67 V

40. $E^0 = 0.52 - 0.16 = 0.36$ V.

$$\log K_{eq} = \frac{nE^0}{0.0592} = \frac{1 \times 0.36}{0.0592} = 6.081.$$

$\therefore \quad K_{eq} = 1.20 \times 10^6.$

46. The cell is represented as

$$\overset{-0.34\ \text{M}}{\text{Tl(s)} \mid \text{Tl}^+(1.0\ \text{M})} \,\|\, \overset{+0.13\ \text{M}}{\text{Sn}^{4+}(1.0\ \text{M}), \text{Sn}^{2+}(1.0\ \text{M}) \mid \text{Pt}}$$

The cell reaction is

$$\text{Tl(s)} \longrightarrow \text{Tl}^+ + e \times 2$$

$$\text{Sn}^{4+} + 2e \longrightarrow \text{Sn}^{2+}$$

Overall reaction $2\text{Tl(s)} + \text{Sn}^{4+} \longrightarrow 2\text{Tl}^+ + \text{Sn}^{2+}$

$$E = (E^0_{\text{Right}} - E^0_{\text{Left}}) - \frac{0.0592}{2} \log \frac{[\text{Tl}^+]^2[\text{Sn}^{2+}]}{[\text{Sn}^{4+}]}$$

$$= 0.47\ \text{V} - 0.0296 \log (10)^2 \quad [\text{Tl}^+ \text{ concentration increases tenfold}]$$

$$= 0.47 - 0.0592 = 0.411\ \text{V}.$$

48. $\log K_{sp} = \dfrac{nE^0}{0.0592}$

$$= \frac{1 \times (-0.58)}{0.0592} = -9.797 = \overline{10}.203 \text{ (here } E^0 = -0.58 \text{ V and } n = 1).$$

$\therefore \quad K_{sp} = 1.6 \times 10^{-10}.$

49. $E_{H^+/H_2} = E^0_{H^+/H_2} - \frac{0.0592}{1} \log \frac{p_{H_2}^{\frac{1}{2}}}{[H^+]}$

$= 0 + 0.0592 \log [H^+] = -0.0592 \text{ pH}$

$= -59.2 \text{ mV} \times \text{pH}.$

51. Ionic velocity is in ms^{-1} and electric field strength is $V\ m^{-1}$, so ionic mobility is $(m\ s^{-1})/V\ m^{-1}$ or $m^2\ s^{-1}V^{-1}$

54. $BeCl_2$ is covalent

56. Smallest ion possesses maximum mobility

58. Water molecules carries in its hydration sphere based on Stokes formula

59. Bi-bivalent nature

61. Uni-univalent strong electrolyte

64. H_2SO_4 is a strong electrolyte

67. $K = \frac{c\Lambda^2}{\Lambda_0(\Lambda_0 - \Lambda)}$

$\Lambda = 1.65 \text{ m S m}^2\text{mol}^{-1}$, $c = 0.01$ M $\quad \Lambda_0 = 39.05 \text{ m S m}^2\text{mol}^{-1}$

72. Electrical property of colloids

73. $I = \frac{V}{R} = VG = \frac{V\kappa A}{l} = V\kappa = Vc(\lambda_0^+ + \lambda_0^-)$

75. $S(\text{Solubility}) = \frac{1000(\kappa_{Agcl} - \kappa_{H_2O})}{\Lambda_0} = \frac{1000(1.86 \times 10^{-6} - 6.0 \times 10^{-8})}{137.2}$

$= 1.3 \times 10^{-5} \text{ mol L}^{-1}$

79. $F(U_+ + U_-)c = G\kappa = c(\lambda_0^+ + \lambda_0^-)$

$F(U_+ + U_-) = \lambda_0^+ + \lambda_0^- = \Lambda_0$

84. Large surface area of the finely divided platinum.

93. $ClO_4^- + 2H^+ + 2e \longrightarrow ClO_3^- + H_2O$

Eq. wt. of $NaClO_4 = \frac{23 + 35 + 64}{2} = 61.25.$

No. of equivalents of $NaClO_4 = \frac{245}{61.25} = 4 \equiv 4.0$ F.

The anode efficiency is 60%.

No. of faradays $= \frac{4.0}{60} \times 100 = 6.67$ F.

$6.67 \text{ F} = 6.67 \times 9.65 \times 10^4 \text{ C} = 6.43 \times 10^5 \text{ C}.$

❑

16

Colligative Properties of Solutions

• *Type 1* •

Choose the correct option. Only one option is correct.

1. The relative lowering of the vapour pressure of an aqueous solution containing a nonvolatile solute is 0.0125. The molality of the solution is

(a) 0.70 (b) 0.50

(c) 0.80 (d) 0.40

2. The vapour pressure of a deliquescent substance is

(a) equal to the atmospheric pressure

(b) equal to that of the water vapour in air

(c) greater than that of the water vapour in air

(d) less than that of the water vapour in air

3. Which of the following aqueous solutions has the highest boiling point?

(a) 0.1 M KNO_3 (b) 0.1 M Na_3PO_4

(c) 0.1 M $BaCl_2$ (d) 0.1 M K_2SO_4

4. Which of the following has been arranged in order of decreasing freezing point?

(a) 0.05 M KNO_3 > 0.04 M $CaCl_2$ > 0.140 M sugar > 0.075 M $CuSO_4$

(b) 0.04 M $BaCl_2$ > 0.140 M sucrose > 0.075 M $CuSO_4$ > 0.05 M KNO_3

(c) 0.075 M $CuSO_4$ > 0.140 M sucrose > 0.04 M $BaCl_2$ > 0.05 M KNO_3

(d) 0.075 M $CuSO_4$ > 0.05 M $NaNO_3$ > 0.140 M sucrose > 0.04 M $BaCl_2$

5. Among the following, the solution which shows the highest osmotic pressure is

(a) 0.05 M NaCl (b) 0.10 M $BaCl_2$

(c) 0.05 M $FeCl_3$ (d) 0.05 M Na_2SO_4

6. The osmotic pressures of equimolar solutions of $BaCl_2$, NaCl and $C_{12}H_{22}O_{11}$ will be in the order

(a) $NaCl > C_{12}H_{22}O_{11} > BaCl_2$

(b) $BaCl_2 > NaCl > C_{12}H_{22}O_{11}$

(c) $NaCl > BaCl_2 > C_{12}H_{22}O_{11}$

(d) $C_{12}H_{22}O_{11} > NaCl > BaCl_2$

7. 10 g of glucose (π_1), 10 g of urea (π_2) and 10 g of sucrose (π_3) are dissolved in 250 mL of water at 300 K (π = osmotic pressure of solution). The relationship between the osmotic pressures of the solutions is

(a) $\pi_1 > \pi_2 > \pi_3$ (b) $\pi_3 > \pi_1 > \pi_2$

(c) $\pi_2 > \pi_1 > \pi_3$ (d) $\pi_2 > \pi_3 > \pi_1$

8. When mercuric iodide is added to an aqueous solution of KI, the

(a) freezing point is raised

(b) freezing point is lowered

(c) boiling point does not change

(d) freezing point does not change

9. Which of the following pairs of solutions can be expected to be isotonic at the same temperature?

(a) 0.1 M urea and 0.1 M NaCl

(b) 0.1 M urea and 0.2 M $MgCl_2$

(c) 0.1 M NaCl and 0.1 M Na_2SO_4

(d) 0.1 M $Ca(NO_3)_2$ and 0.1 M Na_2SO_4

10. If a solute undergoes dimerization and trimerization, the minimum values of the van't Hoff factors are

(a) 0.50 and 1.50 (b) 1.50 and 1.33

(c) 0.50 and 0.33 (d) 0.25 and 0.67

11. At 323 K, the vapour pressure in millimetres of mercury of a methanol-ethanol solution is represented by the equation $p = 120X_A + 140$, where X_A is the mole fraction of methanol. Then the value of $\lim\limits_{X_A \to 1} \dfrac{p_A}{X_A}$ is

(a) 120 mm (b) 140 mm

(c) 260 mm (d) 20 mm

12. The van't Hoff factors i for an electrolyte which undergoes dissociation and association in solvents are respectively

(a) greater than 1 and greater than 1

(b) less than 1 and greater than 1

(c) less than 1 and less than 1

(d) greater than 1 and less than 1

13. A compound X undergoes tetramerization in a given organic solvent. The van't Hoff factor i is

(a) 4.0 (b) 0.25 (c) 0.125 (d) 2.0

14. A solution containing 0.8716 mol L^{-1} of sucrose at 298 K is iso-osmotic with a solution of sodium chloride containing 0.5 mol L^{-1} of NaCl. The degree of dissociation of NaCl is

(a) 0.743 (b) 0.894

(c) 0.876 (d) 0.943

15. Calculate the ebullioscopic constant for water. The heat of vaporization is 40.685 kJ mol^{-1}.

(a) 0.512 K kg mol^{-1} (b) 1.86 K kg mol^{-1}

(c) 5.12 K kg mol^{-1} (d) 3.56 K kg mol^{-1}

16. Calculate the molecular weight of a substance if the freezing point of a solution containing 100 g of benzene and 0.2 g of the substance is 0.17 K below that of benzene. The cryoscopic constant of benzene is 5.16 K kg mol^{-1}.

(a) 70.46 (b) 85.66

(c) 60.23 (d) 178.25

17. An aqueous solution of NaCl freezes at −0.186°C. Given that $K_b^{H_2O} = 0.512$ K kg mol^{-1} and $K_f^{H_2O} = 1.86$ K kg mol^{-1}, the elevation in boiling point of this solution is

(a) 0.0585 K (b) 0.0512 K

(c) 1.864 K (d) 0.0265 K

18. The decrease in the freezing point of an aqueous solution of a substance is 1.395 K and that in the freezing point of a benzene solution of the same substance is 1.280 K. Explain the difference in ΔT. The substance

(a) dissociates in the aqueous solution as well as in the benzene solution

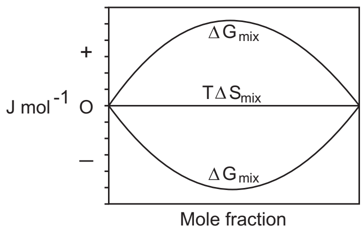
(b) forms complexes in solution

(c) associates in the benzene solution

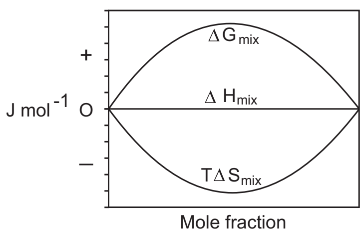
(d) dissociates in the aqueous solution and not in the benzene solution

19. Which of the following represents correctly the changes in thermodynamic properties during the formation of 1 mol of an ideal binary solution.

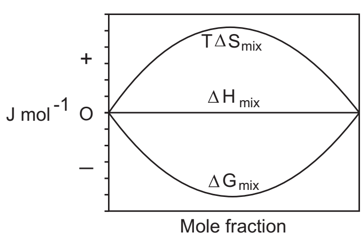
(a)



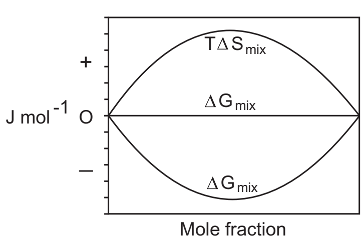
(b)



(c)



(d)



20. Which of the following statements is correct for a binary solution?

(a) A solution in which heat is evolved exhibits positive deviations from Raoult's law.

(b) A solution in which heat is absorbed shows negative deviations from Raoult's law.

(c) When one component in solution shows negative deviation from Raoult's law, the other exhibits positive deviation.

(d) When one component in solution shows positive deviation from Raoult's law, so does the other.

21. The normal boiling point of toluene is 110.7°C, and its boiling point elevation constant is 3.32 K kg mol^{-1}. The enthalpy of vapourization of toluene is nearly

(a) 17.0 kJ mol^{-1} (b) 34.0 kJ mol^{-1}

(c) 51.0 kJ mol^{-1} (d) 68.0 kJ mol^{-1}

22. Consider the following statements.

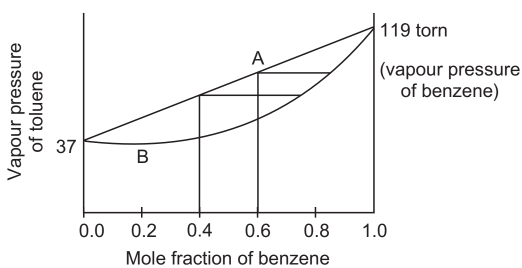
1. Isotonic solutions have the same molar concentration at a given temperature.
2. The molal elevation constant K_b is characteristic of a solvent, and is independent of the solute added.
3. The freezing point of a 0.1 M aqueous KCl solution is more than that of a 0.1 M aqueous $AlCl_3$ solution.

Which of these statements is correct.

(a) 1 and 2 (b) 2 and 3

(c) 1 and 3 (d) 1, 2, and 3

23.



Choose the correct option.

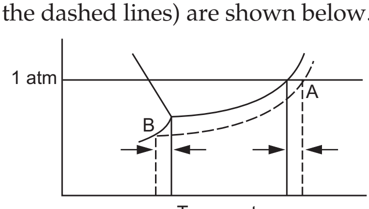
(a) *A* represents vapour composition and *B* liquid composition.

(b) *A* as well as *B* prepresent liquid composition.

(c) Both *A* and *B* represent vapour composition

(d) *A* represents liquid composition and *B* vapour composition.

24. The phase diagrams for a pure solvent (represented by the solid line) and a corresponding solution (containing a nonvolatile solute and represented by the dashed lines) are shown below.



Choose the correct option.

(a) $A = \Delta T_b m$ and $B = \Delta T_f m$

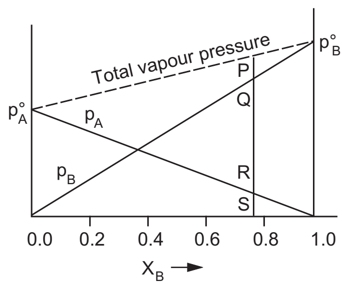
(b) $A = \Delta T_f m$ and $B = \Delta T_b m$

(c) $A = \Delta T_f$ and $B = \Delta T_b$

(d) $A = \Delta T_b$ and $B = \Delta T_f$

where T_f, T_b and m stand for freezing-point temperatures, boiling-point temperature and molality.

25. Consider the following vapour-pressure composition graph.



SP is equal to

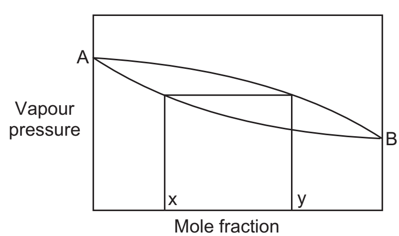
(a) $PQ + RS$

(b) $PQ + QR + RS$

(c) $SR + SQ$

(d) $PQ + QR$

26. Consider the following graph.



Which of the following statements is correct?

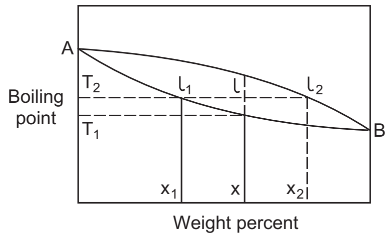
(a) A liquid mixture of composition x is in equilibrium with a vapour mixture of composition y.

(b) A liquid mixture of composition x is in equilibrium with a vapour mixture of composition x.

(c) $x = y^2$

(d) $y = x^2$

27. Consider the following graph pertaining to distillation.



The distillate-to-residue ratio is

(a) $\dfrac{l_1}{l_1 + l_2}$ (b) $\dfrac{lx_1}{lx_2}$ (c) $\dfrac{ll_1}{ll_2}$ (d) $\dfrac{ll_2}{ll_1}$

• *Type 2* •

Choose the correct options. More than one option is correct.

28. When a solute is added to a pure solvent, the

(a) vapour pressure of the solution becomes lower than that of the pure solvent

(b) rate of evaporation of the pure solvent is reduced

(c) solute does not affect the rate of condensation

(d) rate of evaporation of the solution is equal to the rate of condensation of the solution at a lower vapour pressure than that in the case of the pure solvent

29. According to Raoult's law the relative decrease in the solvent vapour pressure over the solution is equal to

(a) the mole fraction of the solvent

(b) the mole fraction of the solute

(c) the number of moles of the solute

(d) i times the mole fraction of the solute which undergoes dissociation or association in the solvent (i = van't Hoff factor)

30. Which of the following combinations are correct for a binary solution, in which the solute as well as the solvent are liquid?

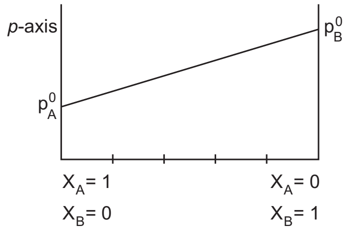
(a) C_6H_6 and $C_6H_5CH_3$; $\Delta H_{soln} > 0$; $\Delta V_{sol} = 0$

(b) CH_3COCH_3 and $CHCl_3$; $\Delta H_{soln} < 0$; $\Delta V_{sol} < 0$

(c) H_2O and HCl; $\Delta H_{soln} > 0$; $\Delta V_{sol} < 0$

(d) H_2O and C_2H_5OH; $\Delta H_{soln} > 0$; $\Delta V_{sol} > 0$

31. The following is a graph plotted between the vapour pressures of two volatile liquids against their respective mole fractions.



Which of the following combinations are correct?

(a) When $x_A = 1$ and $x_B = 0$, then $p = p_A^0$.

(b) When $x_B = 1$ and $x_A = 0$, then $p > p_A^0$.

(c) When $x_A = 1$ and $x_B = 0$, then $p < p_B^0$.

(d) When $x_B = 1$ and $x_A = 0$, then $p = p_B^0$.

32. Which of the following statements are correct for a binary solution which shows negative deviation from Raoult's law?

(a) The negative deviation from linearity diminishes and tends to zero as the concentration of the solution component approaches unity.

(b) When solutions form, their volumes are smaller than the sum of the volumes of their components.

(c) Heat is released during the formation of the solution.

(d) Heat is evolved during the formation of the solution.

33. A binary liquid (AB) shows positive deviation from Raoult's law when

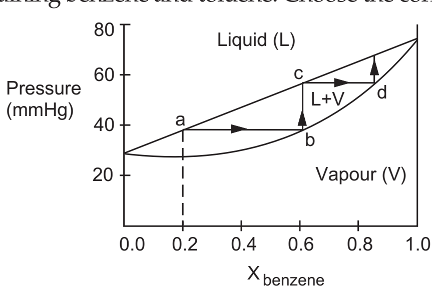
(a) $p_A > p_A^0 X_A^{liq}$ and $p_A > p_B^0 X_B^{liq}$

(b) Intermolecular forces: A–A, B–B > A–B

(c) $\Delta V_{mix} > 0$

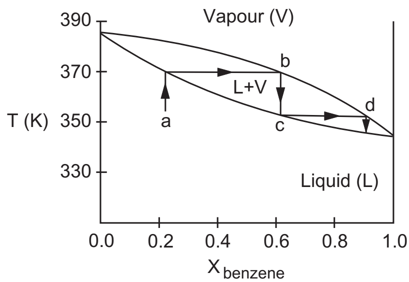
(d) $\Delta H_{mix} > 0$

34. A graph is plotted between the vapour pressure and mole fraction of a solution containing benzene and toluene. Choose the correct options.



(a) At the point *a*, the mole fraction of toluene is 0.80.
(b) $b \rightarrow c$ represents condensation.
(c) $c \rightarrow d$ represents vapourization.
(d) $c \rightarrow d$ represents vapourization as well as condensation.

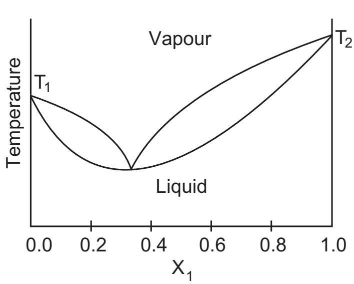
35. A graph is plotted with the temperature of a solution containing benzene and toluene as a function of mole fraction. Choose the correct options.



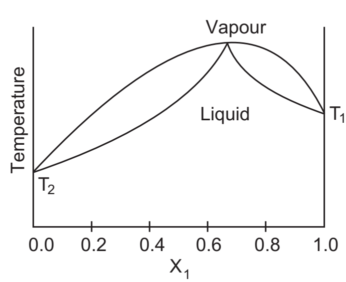
(a) $a \rightarrow b$ represents evaporation.
(b) $b \rightarrow c$ represents condensation.
(c) $c \rightarrow d$ represents evaporation.
(d) $c \rightarrow d$ represents condensation.

36. The azeotropic solutions of two miscible liquids
(a) can be separated by simple distillation
(b) may show positive or negative deviation from Raoult's law
(c) are supersaturated solutions
(d) behave like a single component and boil at a constant temperature

37. The following two graphs are plotted between the temperature and mole fraction of the components of two different azeotropic mixtures. (X_1 = mole fraction of solvent.)



Graph A



Graph B

Choose the correct options.

(a) Graph A represents minimum boiling point and maximum vapour pressure.

(b) Graph B represents maximum boiling point and minimum vapour pressure.

(c) Graph A represents maximum boiling point and minimum vapour pressure.

(d) Graph B represents minimum boiling point and maximum vapour pressure.

38. A substance effloresces

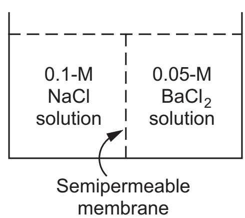
(a) due to the formation of a crust on its crystal surface

(b) when its vapour pressure is greater than that of the water vapour in air

(c) till it melts

(d) when all of the above happen

39. Study the following figure, and choose the correct options.



(a) There will be no movement of any solution across the membrane.

(b) $BaCl_2$ will flow towards the NaCl solution.

(c) NaCl will flow towards the $BaCl_2$ solution.

(d) The osmotic pressure of 0.1 M NaCl is higher than the osmotic pressure of 0.05 M $BaCl_2$, assuming complete dissociation of the electrolyte.

40. In which of the following pairs of solutions will the values of the van't Hoff factor be the same?

(a) 0.05 M $K_4[Fe(CN)_6]$ and 0.10 M $FeSO_4$

(b) 0.10 M $K_4[Fe(CN)_6]$ and 0.05 M $FeSO_4(NH_4)_2SO_4.6H_2O$

(c) 0.20 M NaCl and 0.10 M $BaCl_2$

(d) 0.05 M $FeSO_4(NH_4)_2SO_4.6H_2O$ and 0.02 M $KCl.MgCl_2.6H_2O$

Answers

1. a	**2.** d	**3.** b	**4.** a	**5.** b
6. b	**7.** c	**8.** a	**9.** d	**10.** c
11. c	**12.** d	**13.** b	**14.** a	**15.** a
16. c	**17.** b	**18.** d	**19.** c	**20.** d
21. b	**22.** d	**23.** d	**24.** d	**25.** c
26. a	**27.** b	**28.** a, b, c, d	**29.** b, d	**30.** b, d
31. a, d	**32.** a, b, c	**33.** a, b, c	**34.** a, b, c	**35.** a, b, c
36. b, d	**37.** a, b	**38.** a, b	**39.** b, d	**40.** b, d

Hints to More Difficult Problems

1. As we know,

$$\frac{p^0 - p}{p^0} = X_1 = \text{mole fraction of solute.}$$

The ratio $(p^0 - p)/p^0$ is the relative lowering of vapour pressure, which is equal to 0.0125 here.

$\therefore \quad X_1 = 0.0125.$

The relation between the mole fraction and molality is

$$\left(\frac{1}{X_1} - 1\right) = \frac{1000}{m \times 18} \quad (\text{mol. wt. of } H_2O = 18)$$

or $$\left(\frac{1}{0.0125} - 1\right) = \frac{1000}{m \times 18} \Rightarrow m = 0.70.$$

3. The total molarity of all the ions is maximum in Na_3PO_4 $(0.1 \times 3 = 0.3\ \text{M})$. So it has the highest boiling point.

6. In an aqueous solution, $BaCl_2$ produces the maximum number of ions.

8. The number of molecules decreases due to the formation of a complex.

$$HgI_2 + 2KI \longrightarrow K_2[HgI_4]$$

9. $Ca(NO_3)_2$ and Na_2SO_4 produce the same number of ions with the same molarity.

13.
$$\underset{1-\beta}{4A} \rightleftharpoons \underset{\beta/4}{(A)_4} \qquad i = \frac{1 - \beta + \beta/4}{1} = 1 - \frac{3}{4}\beta.$$

β = degree of association = 1 = (100%). $\quad \therefore \quad i = 1 - \frac{3}{4} = 0.25.$

15. $K_b = \dfrac{RT_0^2M}{1000\Delta H_{vapour}} = \dfrac{8.314 \times (373.15)^2 \times 18}{1000 \times 40.685} \times 10^{-3}$

$= 0.512 \text{ K kg mol}^{-1}$.

17. $\Delta T_b = K_b \times$ molality and $\Delta T_f = K_f \times$ molality.
For the same solution, the molality is the same,

or $\dfrac{\Delta T_b}{\Delta T_f} = \dfrac{K_b}{K_f}$

or $\dfrac{\Delta T_b}{0.186} = \dfrac{0.512}{1.86} \Rightarrow \Delta T_b = 0.0512$ K.

20. Molecule-solvent interaction

21. $K_b = \dfrac{RT_0^2M_1}{1000\Delta H_{vap}} \Rightarrow \Delta H_{vap} = \dfrac{RT_0^2M_1}{1000K_b}$.

We know that

$T_0 = 110.7 + 273.15 = 383.15$ K.

M_1 = mol mass of toluene

$= 92 \text{ g mol}^{-1}$.

$K_b = 3.32 \text{ K kg mol}^{-1}$.

$\therefore \quad \Delta H_{vap} = \dfrac{8.314 \times (383.15)^2 \times 92}{1000 \times 3.32 \times 10^3} = 34 \text{ kJ mol}^{-1}$.

30. Both pairs form non-ideal solutions.

33. Intermolecular force of attraction

36. They form a nonideal solution.

40. Both pairs in (b) and (d) produce the same total number of ions after dissociation.

❑

17

Solid-State Chemistry

• *Type 1* •

Choose the correct option. Only one option is correct.

1. Argon crystallizes in a structure in which the atoms are located at the positions (0, 0, 0), $\left(0, \frac{1}{2}, \frac{1}{2}\right)$, $\left(\frac{1}{2}, 0, \frac{1}{2}\right)$ and $\left(\frac{1}{2}, \frac{1}{2}, 0\right)$. The unit cell is

(a) simple cubic
(b) body-centred cubic
(c) face-centred cubic
(d) hexagonal close packed

2. Potassium metal crystallizes in the form of a body-centred cubic structure. The number of nearest-neighbour atoms for each potassium atom in the solid is

(a) four
(b) six
(c) twelve
(d) eight

3. The number of molecules per unit cell for a compound that crystallizes in the form of an orthorhombic end-centred lattice with a molecule at each lattice site is

(a) one
(b) two
(c) four
(d) six

4. NiO adopts a rock-salt structure. The coordination number of the Ni^{2+} ion is

(a) two
(b) four
(c) twelve
(d) six

5. Consider the structure of rock-salt. How many Na^+ ions occupy the second–nearest neighbour location of an Na^+ ion?

(a) 6
(b) 12
(c) 18
(d) 24

6. Which type of crystals contain the maximum number of Bravais lattices?

(a) Cubic (b) Triclinic

(c) Orthorhombic (d) Tetragonal

7. A compound contains two types of atoms—X and Y. It crystallizes in a cubic lattice with atoms X at the corners of the unit cell and atoms Y at the body centres. The simplest possible formula of this compound is

(a) X_8Y (b) X_2Y

(c) XY (d) XY_8

8. Which of the following solids is amorphous?

(a) Fe metal (b) Fused quartz

(c) Wurtzite (d) NiAs

9. Which of the following expressions is correct for a CsCl unit cell with lattice parameter a?

(a) $r_{Cs^+} + r_{Cl^-} = 2a$ (b) $r_{Cs^+} + r_{Cl^-} = \frac{a}{\sqrt{2}}$

(c) $r_{Cs^+} + r_{Cl^-} = \frac{\sqrt{3}}{2}a$ (d) $r_{Cs^+} + r_{Cl^-} = \frac{3a}{2}$

10. Imagine the construction of an MX_2 structure from the bcc CsCl structure by the removal of half the Cs^+ ions so that there is tetrahedral coordination around each Cl^-. What is the structure of MX_2?

(a) An antifluorite (Na_2O) structure

(b) A fluorite (CaF_2) structure

(c) A rutile (TiO_2) structure

(d) A pyrolusite (MnO_2) structure

11. The molecules NaCl, MgO and NiO show 6 : 6 coordination, but BeO exhibits 4 : 4 coordination because

(a) BeO is covalent (b) BeO is ionic

(c) BeO is amphoteric (d) BeO is polymeric

12. The lattice parameters of a given crystal are $a = 5.62$ Å, $b = 7.41$ Å and $c = 9.48$ Å. The three coordinate axes are mutually perpendicular to each other. The crystal is

(a) tetragonal (b) orthorhombic

(c) monoclinic (d) trigonal

13. In diamond, the coordination number of carbon is

(a) four and its unit cell has eight carbon atoms

(b) four and its unit cell has six carbon atoms

(c) six and its unit cell has four carbon atoms

(d) four and its unit cell has four carbon atoms

14. In NaCl, the centre-to-centre nearest-neighbour distance of ions is

(a) $\frac{1}{4}a$ (b) $\frac{\sqrt{3}}{2}a$

(c) $\frac{1}{2}a\sqrt{2}$ (d) $\frac{1}{2}a$

where a is the lattice parameter.

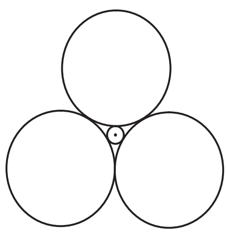
15. Calculate the ionic radius of a Cs^+ ion, assuming that the cell-edge length for CsCl is 0.4123 nm and that the ionic radius of a Cl^- ion is 0.181 nm.

(a) 0.176 nm (b) 0.231 nm

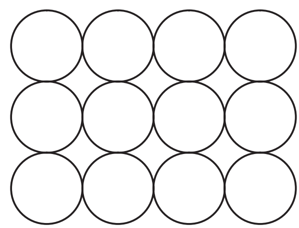
(c) 0.352 nm (d) 0.116 nm

16. Which of the following figures represents the cross-section of an octahedral site?

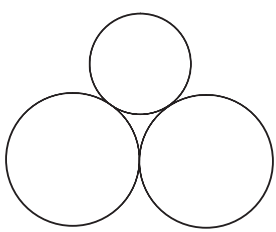
(a)



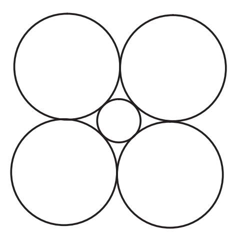
(b)



(c)



(d)



17. Zinc sulphide exists in two different forms—zinc blende and wurtzite. Both occur as 4 : 4 coordination compounds. Choose the correct option from among the following.

(a) Zinc blende has a bcc structure and wurtzite an fcc structure.

(b) Zinc blende has an fcc structure and wurtzite an hcp structure.

(c) Zinc blende as well as wurtzite have a hcp structure.

(d) Zinc blende as well as wurtzite have a cpp structure.

18. Consider the radii 0.095 nm (Na^+), 0.181 nm (Cl^-), 0.074 nm (Zn^{2+}), 0.184 nm (S^{2-}), 0.068 nm (Ti^{4+}), 0.140 nm(O^{2-}), 0.169 nm (Cs^+). Choose the correct option from among the following. (Use radius ratio rules.)

(a) Na^+ ions are packed in octahedral holes between the planes of close-packed Cl^- ions.

(b) Zn^{2+} ions are packed in tetrahedral holes.

(c) Cs^+ ions are packed in a simple cubic array of Cl^- ions.

(d) All of these

19. Every atom or ion that forms an fcc unit cell is surrounded by

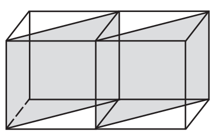
(a) six octahedral holes and eight tetrahedral holes

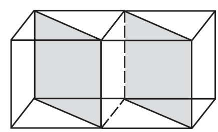
(b) eight octahedral holes and six tetrahedral holes

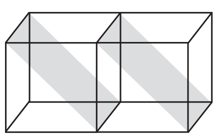
(c) six octahedral holes and six tetrahedral holes

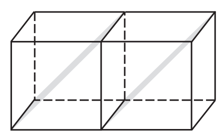
(d) eight octahedral holes and four tetrahedral holes

20. Which of the following figures represents a 110 plane?

(a) 

(b) 

(c) 

(d) 

21. Which of the following expressions is correct for an NaCl unit cell with lattice parameter *a*?

(a) $r_{Na^+} + r_{Cl^-} = \frac{a}{\sqrt{2}}$

(b) $r_{Na^+} + r_{Cl^-} = 4a$

(c) $r_{Na^+} + r_{Cl^-} = \frac{a}{4}$

(d) $r_{Na^+} + r_{Cl^-} = \frac{\sqrt{3}}{4}a$

22. Consider the structure of CsCl (8 : 8 coordination). How many Cs^+ ions occupy the second-nearest neighbour locations of a Cs^+ ion?

(a) 8

(b) 24

(c) 6

(d) 16

23. The addition of a $CaCl_2$ crystal to a KCl crystal

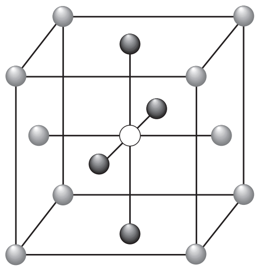
(a) lowers the density of the KCl crystal

(b) raises the density of the KCl crystal

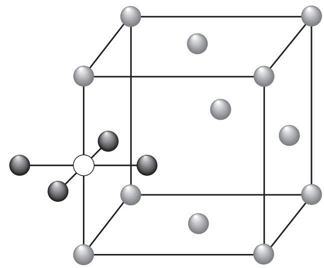
(c) does not affect the density of the KCl crystal

(d) increases the Frenkel defects of the KCl crystal

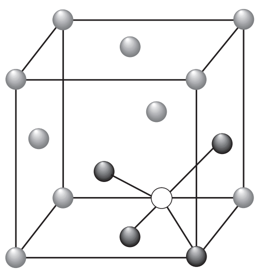
24. Consider the following fcc unit cells choose the correct option.



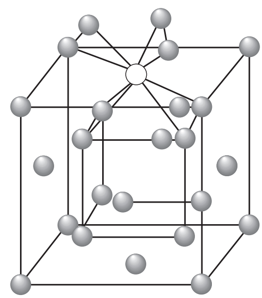
I



II



III



IV

(a) I and II represent tetrahedral holes.
(b) II, III and IV represent tetrahedral holes.
(c) I and II represent octahedral holes.
(d) I, II and IV represent octahedral holes.

25. Iron crystallizes in a bcc system with a lattice parameter of 2.861 Å. Calculate the density of iron in the bcc system (atomic weight of Fe = 56, $N_A = 6.02 \times 10^{23}$ mol^{-1}).

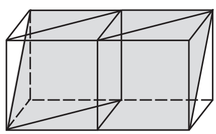
(a) 7.92 g mL^{-1} (b) 8.96 g mL^{-1}
(c) 2.78 g mL^{-1} (d) 6.72 g mL^{-1}

26. Bragg reflection can occur only for

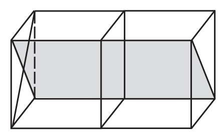
(a) $\lambda \le 2d$ (b) $\lambda \ge 2d$
(c) $\lambda > 2d$ (d) none of these

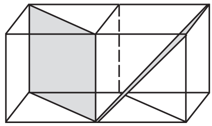
27. The shaded area in which of the following figures represents a 101 plane?

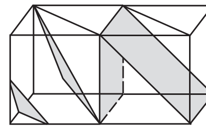
(a)



(b)



(c) 

(d) 

28. Nickel crystallizes in an fcc unit cell with a cell-edge length of 0.3524 nm. Calculate the radius of the nickel atom.

(a) 0.1624 nm (b) 0.1246 nm (c) 0.2164 nm (d) 0.1426 nm

29. In which of the following pairs of structures are tetrahedral as well as octahedral holes found?

(a) bcc and fcc
(b) hcp and simple cubic
(c) hcp and ccp
(d) bcc and hcp

30. The effective nuclear charges of Na^+ and F^- ions are 6.50 and 4.50 respectively. If $r_{Na^+} + r_{F^-} = 231$ pm, calculate the radii of Na^+ and F^- ions.

(a) $r_{Na^+} = 94.5$ pm, $r_{F^-} = 46.5$ pm.
(b) $r_{Na^+} = 94.5$ pm, $r_{F^-} = 136.5$ pm.
(c) $r_{Na^+} = 136.5$ pm, $r_{F^-} = 94.5$ pm.
(d) $r_{Na^+} = 36.0$ pm, $r_{F^-} = 92.0$ pm.

31. KCl crystallizes in the same type of lattice as does NaCl. Given that $r_{Na^+}/r_{Cl^-} = 0.55$ and $r_{Na^+}/r_{K^+} = 0.74$, calculate the ratio of the side of the unit cell for KCl to that for NaCl.

(a) 1.122 (b) 1.224 (c) 1.414 (d) 0.732

32. The relation between the *d*-spacing formula and the Bragg equation for a cubic crystal for first-order reflection is

(a) $\sin\theta = \frac{\lambda}{2a}(h^2 + k^2 + l^2)^2$
(b) $\sin\theta = \frac{\lambda}{2a}(h^2 + k^2 + l^2)^{1/2}$
(c) $\sin\theta = \frac{2a}{\lambda}(h^2 + k^2 + l^2)^{1/2}$
(d) $\sin\theta = \frac{2a}{\lambda}(h^2 + k^2 + l^2)^{1/2}$

33. The orientation of a lattice plane is determined according to its

(a) Scattering factor
(b) Bravais lattice
(c) nearest neighbour
(d) Miller indices

34. Perovskite is a mineral with the formula $CaTiO_3$. Which of the positive ions in the crystal is more likely to be packed in the octahedral holes?

(a) Ti^{4+} (b) Ti^{2+} (c) Ca^{2+} (d) O_2^+

35. Which of the following statements is incorrect?

(a) A substitutional solid solution is one in which atoms of the solute metal occupy some locations that solvent metal atoms are expected to occupy.

(b) An interstitial solid solution is one in which the solute atoms occupy the interstices (holes) between the solvent atoms.

(c) An intermetallic compound is a compound formed between metals and metalloids.

(d) Cu_3Zn is an intermetallic compound.

36. The unit cell of $CO_2(s)$ is

(a) fcc (b) bcc (c) linear (d) hcp

37. Because of anisotropy

(a) mica cleaves into thin sheets and asbestos cleaves into long, rod-like pieces

(b) mica cleaves into long, rod-like pieces and asbestos cleaves into thin sheets

(c) mica as well as asbestos cleave into thin sheets

(d) mica as well as asbestos cleave into long, rod-like pieces

38. In NaCl the centres of two nearest like-charged ions are at a distance of

(a) $\frac{1}{2}a\sqrt{2}$ (b) $\frac{1}{2}a$ (c) $\frac{\sqrt{3}}{2}a$ (d) $\frac{1}{\sqrt{2}}2a$

from each other.

39. Which of the following compounds represent an inverse 2 : 3 spinel structure?

(a) $Fe^{III}(Fe^{II}Fe^{III})O_4$ (b) PbO_2

(c) Al_2O_3 (d) Mn_3O_4

40. M_2X compounds have a structure closely related to that of flourite. These compounds are said to have an antifluorite structure. In such a structure,

(a) the smaller cations occupy the position of the fluoride ions and the larger anions that of the calcium ions

(b) the larger cations occupy the position of the fluoride ions and the smaller anions that of the calcium ions.

(c) Each fluoride ion is surrounded by four calcium ions in a tetrahedral arrangement.

(d) Fluoride ions occupy all the eight octahedral holes.

41. Which of the following pairs have fcc lattice structures?

(a) Rock salt and Wurtzite (b) Rock salt and sphalerite

(c) CsCl and rutile (d) Polonium and fluorite

42. Which of the following statements is incorrect for sphalerite, a form of ZnS?

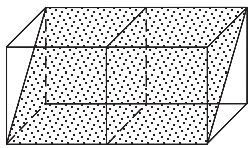
(a) It has the same structure as diamond, except that the alternate atoms are zinc and sulphur.

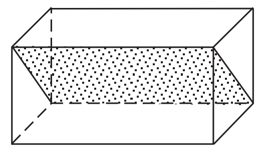
(b) Because the sulphide ion is larger than the zinc ion, only six rather than four or eight sulphide ions can be packed around a zinc ion.

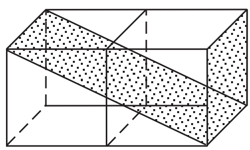
(c) Because the sulphide ion is larger than the zinc ion, only four rather than six or eight sulphide ions can be packed around a zinc ion.

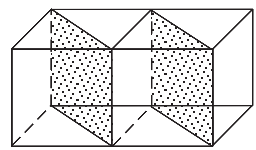
(d) ZnS is polar covalent.

43. Which of the following figures represents the $(\bar{1}\,0\,1)$ plane?

(a) 

(b) 

(c) 

(d) 

44. Which of the following statements is correct?

(a) The crystal structure of rock salt is an fcc array of anions in which the cations occupy all the octahedral holes (or vice versa)

(b) The sphalerite crystal structure is an expanded fcc anion lattice with cations occupying one type of tetrahedral hole.

(c) In the flourite crystal structure, cations occupy half the cubic holes of a primitive cubic array of anions.

(d) All of these.

45. If the three interaxial angles defining the unit cell are all equal in magnitude, the crystal cannot be

(a) rhombohedral (b) cubic

(c) hexagonal (d) tetragonal

46. Which of the following statements is correct for the NaCl lattice?

(a) An Na^+ ion is placed at a distance $\frac{1}{6}a$ directly above each Cl^- ion (where a is the cubic unit-cell edge length).

(b) An Na^+ ion is placed at a distance $\frac{1}{4}a$ directly above each Cl^- ion.

(c) An Na^+ ion is placed at a distance of $\frac{1}{2\sqrt{2}}a$ directly above each Cl^- ion.

(d) An Na^+ ion is placed at a distance $\frac{1}{\sqrt{2}}a$ directly above each Cl^- ion.

47. Which of the following statements is correct?

(a) A rutile (TiO_2) structure consists of an hcp anion lattice with cations occupying half the octahedral holes.

(b) The Wurtzite structure is derived from an expanded hcp anion array with cations occupying one type of octahedral holes.

(c) In the fluorite structure (CaF_2), anions occupy both types of tetrahedral holes in an expanded fcc lattice of cations.

(d) All the these

48. When the radius ratios lie between 0.732 and 0.414, the arrangement of the crystal is

(a) tetrahedral (b) octahedral

(c) linear (d) cubic

49. An fcc cubic cell contains eight X atoms at the corners of the cell and six Y atoms at the faces. What is the empirical formula of the solid?

(a) X_3Y_4 (b) X_3Y

(c) XY_3 (d) X_4Y_3

50. The spinel structure (AB_2O_4) consists of an fcc array of O^{2-} ions in which the

(a) A cation occupies one-eighth of the tetrahedral holes and the B cations the octahedral holes

(b) A cation occupies one-fourth of the tetrahedral holes and the B cations the octahedral holes

(c) A cation occupies one-eighth of the octahedral holes and the B cation the tetrahedral holes

(d) A cation occupies one-fourth of the octahedral holes and the B cations the tetrahedral holes

51. Which of the following statements is incorrect for the diamond structure?

(a) Each atom has 4 nearest neighbours and 12 next-nearest neighbours.

(b) It is relatively empty.

(c) The maximum proportion of the available volume which may be filled by hard spheres is only 0.34.

(d) The maximum proportion of the available volume which may be filled by hard spheres is only 0.46.

52. In an NaCl structure,

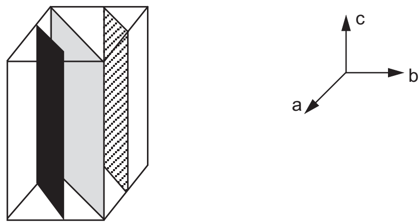
(a) 4 corners are shared

(b) 6 corners and 2 edges are shared

(c) 3 edges are shared

(d) 12 edges are shared

53. If the shaded plane



intercepts the a axis at $a/2$, the b axis at $b/2$, and lies parallel to the c axis, then its Miller indices are

(a) $\left(\frac{1}{2}\ \frac{1}{2}\ 0\right)$ (b) $\left(0\ \frac{1}{2}\ \frac{1}{2}\right)$
(c) (2 2 0) (d) (2 1 0)

54. For a given crystal the lattice parameter a is 318 pm. The d-spacing for a (III) plane is

(a) 225 pm (b) 184 pm
(c) 318 pm (d) 390 pm

55. All the positions in an fcc lattice are occupied by A atoms, and the bcc octahedral hole in it by a B atom of appropriate size. The formula of the compound is

(a) A_2B (b) AB_4 (c) A_4B (d) A_4B_3

56. The zinc blende structure results when the Zn atoms occupy one

(a) fcc lattice and the S atoms another
(b) bcc lattice and the S atoms another
(c) bcc lattice and the S atoms an fcc lattice
(d) sc lattice and the S atoms another

57. A metal of density 7.5×10^3 kg m^{-3} has an fcc crystal structure with lattice parameter $a = 400$ pm. Calculate the number of unit cells present in 0.015 kg of the metal.

(a) 6.250×10^{22} (b) 3.125×10^{23}
(c) 3.125×10^{22} (d) 1.563×10^{22}

58. The molar volume of KCl and NaCl are 37.46 mL and 27.94 mL respectively. The ratio of the unit cube edges of the two crystals is

(a) 1.296 (b) 1.116
(c) 1.341 (d) 0.950

59. When the radius ratio r_M/r_X of a crystal lies in the range 0.414–0.732, the coordination number of M and its corresponding crystal is

(a) 4, TiO_2 (b) 6, ZnS (c) 8, CsCl (d) 6, TiO_2

60. The ratio of the volume of a tetragonal lattice to that of a hexagonal lattice is

(a) $\frac{\sqrt{3}}{2}abc$ (b) $\frac{2}{\sqrt{3}}$ (c) $\frac{2}{\sqrt{3}}\frac{a^2}{b}c$ (d) $\frac{\sqrt{3}}{2}\frac{a^2}{bc}$

61. If a metal has a bcc crystal structure, the coordination number is 8, because

(a) each atom touches four atoms in the layer above it, four in the layer below it and none in its own layer

(b) each atom touches four atoms in the layer above it, four in the layer below it and one in its own layer

(c) two atoms touch four atoms in the layer above them, four in the layer below them, and none in their own layer

(d) each atom touches eight atoms in the layer above it, eight in the layer below it and none in its own layer

62. An fcc lattice has a lattice parameter $a = 400$ pm. Calculate the molar volume of the lattice including all the empty space.

(a) 10.8 mL (b) 96 mL

(c) 8.6 mL (d) 9.6 mL

63. In a ccp structure, the

(a) first and third layers are repeated

(b) first and fourth layers are repeated

(c) second and fourth layers are repeated

(d) first, third and sixth layers are repeated

64. In hcp (ABAB…) and ccp (ABCABC…) structures made up of spheres of equal size, the volume occupied per sphere is (a = radius of sphere)

(a) $5.66a^3$ (b) $1.33a^3$

(c) $2.66a^3$ (d) $7.40a^3$

65. Which of the following statements is incorrect for a two-dimensional hexagonal close-packed layer?

(a) Each sphere is surrounded by six.

(b) Each sphere is surrounded by six voids.

(c) Each sphere has three voids.

(d) Each void is surrounded by three spheres.

66. Which of the following mechanisms is incorrect for a stoichiometrically pure compound AB?

(a) There is a displacement of A atoms to interstitial sites, leaving an equal number of A-type vacancies in the structure.

(b) There is a displacement of B atoms to interstitial sites, accompanied by the formation of an equal number of B-type vacancies.

(c) An equal number of A- and B-type vacancies are created by the migration of atoms to the crystal surface.

(d) An equal number of interstitial A and B atoms, and A- and B-type vacancies, are created.

67. Suppose there are N atoms in a crystal with N_i interstitial positions in its structure. If there are n Frenkel defects in the crystal then

(a) $n = (NN_i) \exp(-E_i/2k_BT)$ (b) $N = (nN_i)^{1/2} \exp(-E_i/2k_BT)$

(c) $n = (NN_i)^{1/2} \exp(-E_i/2k_BT)$ (d) $n = (NN_i)^{1/2} \exp(+E_i/2k_BT)$

where E_i is the energy required to remove an atom from a lattice site to an interestitial position.

68. Crystals may be coloured by

(a) the introduction of chemical impurities

(b) X-ray, γ-ray and electron bombardment

(c) introducing an excess of the metal

(d) all these methods

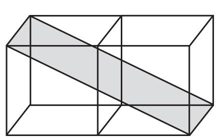
69. The radius ratio (γ_M/γ_X) for cation-anion and anion-anion contact for a tetrahedral arrangement of anions around a cation is

(a) 0.414 (b) 0.225

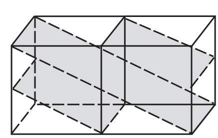
(c) 1.00 (d) 0.732

70. Which of the following shaded areas of the figures represent (002) planes?

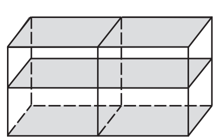
(a)



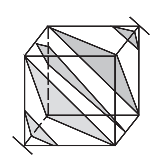
(b)



(c)



(d)



71. The numbers of tetrahedral and octahedral holes in a ccp array of 100 atoms are respectively

(a) 200 and 100 (b) 100 and 200

(c) 200 and 200 (d) 100 and 100

72. Copper crystallizes in an fcc form and sodium in a bcc form. The coordination numbers of Cu and Na are respectively

(a) 12 and 12 (b) 12 and 8

(c) 8 and 12 (d) 6 and 8

73. In AgCl, the silver ion is displaced from its lattice position to an interstitial position. Such a defect is called a

(a) Schottky defect (b) Frenkel defect
(c) Wadsley defect (d) colour centre

74. A solid solution of $CdBr_2$ in AgBr contains

(a) Schottky defects
(b) Frenkel defects
(c) Frenkel as well as Schottky defects
(d) colour centres

75. NaCl shows Schottky defects and AgCl Frenkel defects. Their electrical conductivity is due to the

(a) motion of ions and not the motion of electrons
(b) motion of electrons and not the motion of ions
(c) lower coordination number of NaCl
(d) higher coordination number of AgCl

76. If a crystal contains a total of N atoms, and n Schottky defects are produced by removing n cations and r anions from the interior of the crystal, then

(a) $n = N \exp(-E_p/2k_BT)$ (b) $N = n \exp(-E_p/2k_BT)$
(c) $n = N \exp(-E_p/k_BT)$ (d) $n = N \exp(E_p/k_BT)$

when E_p is the energy of the formation of a pair, k_B is the Boltzmann constant and T is the temperature in kelvin.

77. Which of the following statements is correct for a close-packed structure?

(a) Each octahedral void is surrounded by six spheres and each sphere is surrounded by six octahedral voids.
(b) Each octahedral void is surrounded by six spheres and each sphere is surrounded by three octahedral voids.
(c) Each octahedral void is surrounded by six spheres and each sphere is surrounded by eight octahedral voids.
(d) Each octahedral void is surrounded by eight spheres and each sphere is surrounded by six octahedral voids.

78. The coordination number of the fcc structure for metals is 12, since

(a) each atom touches four others in the same layer, three in the layer above and three in that below
(b) each atom touches four others in the same layer, four in the layer above and four in that below
(c) each atom touches six others in the same layer, six in the layer above, and six in that below

(d) each atom touches three others in the same layer, six in the layer above and six in that below

79. Amorphous solids may be classified as

(a) isotropic and supercooled liquids

(b) anisotropic and supercooled liquids

(c) isoenthalpic and superheated liquids

(d) isotropic and superheated solids

80. In the face-centred cubic lattice structure of gold, the closest distance between gold atoms (the length of the cubic unit cell being a) is

(a) $\frac{1}{4}a\sqrt{2}$ (b) $\frac{1}{4}(a\sqrt{2})$

(c) $a\sqrt{2}$ (d) $\frac{1}{2}\frac{a}{\sqrt{2}}$

81. How many octahedral sites per sphere are there in a cubic close-packed structure?

(a) four (b) two (c) one (d) six

82. A compound alloy of gold and copper crystallizes in a cubic lattice in which the gold atoms occupy the lattice points at the corners of a cube and a copper atom occupies the centre of each cube face. The formula of this compound is

(a) Au_3Cu (b) $AuCu_3$

(c) Au_4Cu (d) $AuCu_2$

83. In the structure of diamond, the carbon atoms appear at

(a) $0\ 0\ 0$ and $\frac{1}{2}\ \frac{1}{2}\ \frac{1}{2}$ (b) $\frac{1}{4}\ \frac{1}{4}\ \frac{1}{4}$ and $\frac{1}{2}\ \frac{1}{2}\ \frac{1}{2}$

(c) $0\ 0\ 0$ and $\frac{1}{4}\ \frac{1}{4}\ \frac{1}{4}$ (d) $0\ 0\ 0$ and $\frac{3}{4}\ \frac{3}{4}\ \frac{3}{4}$

84. The lattice of crystalline $CoCl_2$ is body-centred tetragonal with 16 formula units per unit cell. How many molecules does the basis consist of?

(a) 8 (b) 16 (c) 4 (d) 2

85. Which of the following statements is correct for a cubic close-packed structure?

(a) There are three sites. (b) There are two types of sites.

(c) There are four types of sites. (d) There are six types of sites.

86. The bond lengths and bond angles in molecules in the solid state are calculated by the X-ray diffraction technique because X-rays are scattered by

(a) electrons (b) positrons

(c) protons (d) neutrons

87. All spinel structures have a

(a) ccp array of anions

(b) simple cubic structure

(c) bcc array of anions

(d) hexagonal close-packed array of anions

88. Which of the following statements are correct in the context of point defects in a crystal?

(a) AgCl has anion Frenkel defects and CaF_2 has Schottky defects.

(b) AgCl has cation Frenkel defects and CaF_2 has anion Frenkel defects.

(c) AgCl as well as CaF_2 have anion Frenkel defects.

(d) AgCl as well as CaF_2 have Schottky defects.

89. A solid is made of two elements, A and B. The atoms of A are arranged in a ccp structure and those of B occupy all the tetrahedral sites. The formula of the compound is

(a) AB_2 (b) A_2B (c) A_2B_3 (d) A_3B_2

90. Barium titanate has a pyrolusite structure (a cubic lattice), with barium ions occupying the corners of the unit cell, oxide ions the face centres and titanium ions the centres. Asuming that Ti^{4+} ions occupy the holes of the BaO lattice, what type of hole and what fraction of such holes do these ions occupy?

(a) 25% of the octahedral holes (b) 75% of the tetrahedral holes

(c) 50% of the tetrahedral holes (d) 100% of the octahedral holes

91. Three elements P, Q and R crystallize in a cubic solid lattice. The P atoms occupy the corners, Q atoms the cube centres and R atoms the edges. The formula of the compound is

(a) PQR (b) PQR_2 (c) PQR_3 (d) PQ_3R

• Type 2 •

Choose the correct options. More than one option is correct.

92. Which type of crystals contain one Bravais lattice?

(a) Hexagonal (b) Triclinic

(c) Rhombohedral (d) Monoclinic

93. Which of the following crystals have 8 : 8 coordination?

(a) NH_4Cl (b) AlFe

(c) MnO (d) NH_4Br

94. Which of the following crystals have 6 : 6 coordination?
(a) NH_4I
(b) MgO
(c) MnO
(d) ZnS

95. Which of the following crystals have 4 : 4 coordination?
(a) HgS
(b) NH_4F
(c) SiC
(d) NaCl

96. The fluorite structure shows 8 : 4 coordination. Which of the following solids have fluorite-like lattices?
(a) CaF_2
(b) $SrCl_2$
(c) BaF_2
(d) ThO_2

97. TiO_2 (rutile) shows 6 : 3 coordination. Which of the following solids have a rutile-like structure?
(a) MnO_2
(b) ZnS
(c) KCl
(d) SnO_2

98. Which of the following structures have layered lattices?
(a) Cadmium iodide
(b) Ice
(c) Graphite
(d) Diamond

99. Which of the following crystals show 4 : 2 coordination?
(a) CaF_2
(b) BeF_2
(c) SiO_2
(d) PbO_2

100. The hcp and ccp structure for a given element would be expected to have
(a) the same coordination number
(b) the same density
(c) the same packing fraction
(d) all the above

101. In an NaCl structure, all the
(a) octahedral sites are occupied
(b) tetrahedral sites are unoccupied
(c) octahedral as well as the tetrahedral sites are occupied
(d) octahedral as well as the tetrahedral sites are unoccupied

102. Which of the following statements are correct for the rock-salt structure?
(a) The tetrahedral sites are smaller than the octahedral sites.
(b) The octahedral sites are occupied by cations and the tetrahedral sites are empty.
(c) The radius ratio is 0.732.
(d) The radius ratio is 0.999.

103. Which of the following compounds represent a normal 2 : 3 spinel structure?

(a) $Mg^{II}Al_2^{III}O_4$ (b) $Co^{II}(Co^{III})_2O_4$

(c) $Zn(TiZn)O_4$ (d) $Ni(CO)_4$

104. Which of the following statements are correct?

(a) The coordination number of each type of ion in a CsCl crystal is eight.

(b) A metal that crystallizes in a bcc structure has a coordination number of twelve.

(c) A unit cell of an ionic crystal shares some of its ions with other unit cells.

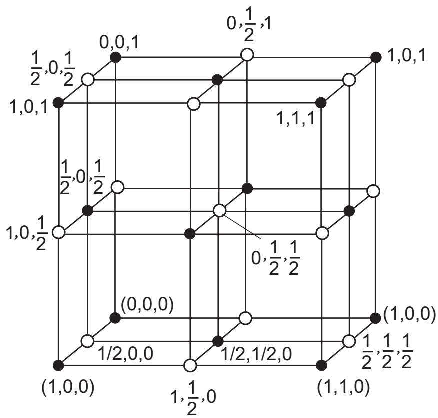
(d) The length of the unit cell in NaCl is 552 pm (given that $r_{Na^+} = 95$ pm and $r_{Cl^-} = 181$ pm.

Answers

1. c	**2.** d	**3.** b	**4.** d	**5.** b
6. c	**7.** c	**8.** b	**9.** c	**10.** b
11. a	**12.** b	**13.** a	**14.** d	**15.** a
16. d	**17.** b	**18.** d	**19.** a	**20.** a
21. a	**22.** c	**23.** a	**24.** c	**25.** a
26. a	**27.** a	**28.** b	**29.** c	**30.** b
31. a	**32.** b	**33.** d	**34.** a	**35.** c
36. a	**37.** a	**38.** a	**39.** a	**40.** a
41. b	**42.** b	**43.** b	**44.** d	**45.** c
46. b	**47.** d	**48.** b	**49.** c	**50.** a
51. d	**52.** d	**53.** c	**54.** b	**55.** c
56. a	**57.** c	**58.** b	**59.** b	**60.** b
61. a	**62.** d	**63.** b	**64.** a	**65.** c
66. d	**67.** c	**68.** d	**69.** b	**70.** c
71. a	**72.** b	**73.** b	**74.** c	**75.** a
76. a	**77.** a	**78.** b	**79.** a	**80.** b
81. c	**82.** b	**83.** c	**84.** a	**85.** b
86. a	**87.** a	**88.** b	**89.** b	**90.** a
91. c	**92.** a, b, c	**93.** a, b, d	**94.** a, b	**95.** a, c
96. a, b	**97.** a, d	**98.** a, c	**99.** b, c	**100.** a, c
101. a, b	**102.** a, c	**103.** a, b	**104.** a, c	

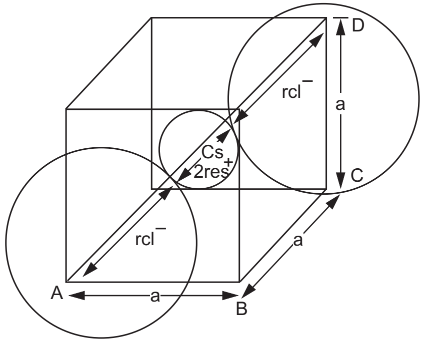
Hints to More Difficult Problems

1.



4. The coordination number of Na in NaCl and that of Cl in the same compound is six, which is same as that of the Ni ion in NiO.

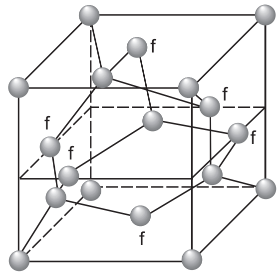
9. CsCl has a bcc structure.



$$AD^2 = AC^2 + CD^2$$
$$= (a\sqrt{2})^2 + a^2 = 3a^2 \Rightarrow AD = a\sqrt{3}.$$

Also, $AD = r_{Cl^-} + 2r_{Cs^+} + r_{Cl^-} = a\sqrt{3} \Rightarrow r_{Cs} + r_{Cl^-} = \dfrac{\sqrt{3}}{2}a$

13. The space lattice of diamond is fcc. The primitive basis has two identical atoms (0, 0, 0), (¼, ¼, ¼) associated with each point of the fcc lattice. (see the figure.). Thus the conventional unit cube contains eight atoms. Also diamond is tetrahedral.



15. CsCl has a bcc lattice. So $d_{\text{body}} = a\sqrt{3}$

or $\quad d_{\text{body}} = \sqrt{3} \times 0.4123 \text{ nm} = 0.7141 \text{ nm}.$

The sum of the ionic radii of Cs^+ and Cl^- ions is half this distance, i.e.,

$$r_{Cs^+} + r_{Cs^-} = \frac{d_{\text{body}}}{2} = \frac{0.7141}{2} \text{ nm} = 0.3571 \text{ nm}.$$

16. The cross-section of an octahedral hole is represented by (a). The octahedral holes are surrounded by six atoms arranged at the corners of an octahedron.

19. Focus on the atoms in the centre of the top face of the unit cell.

25. $\rho = \dfrac{ZM}{N_A a^3}\cdot$ For bcc, $Z = 2$.

$$\rho_{Fe} = \frac{(2) \times 56.0 \text{ g mol}^{-1}}{(6.02 \times 10^{23} \text{ mol}^{-1})(2.861 \times 10^{-8}) \text{ cm}^3} = 7.92 \text{ g cm}^{-3}.$$

28. For an fcc lattice,

$$d_{\text{face}} = a\sqrt{2}$$

or $\quad 4r_{Ni} = a\sqrt{2}.$

$$r_{Ni} = \frac{a\sqrt{2}}{4} = \frac{\sqrt{2}}{4} \times 0.3524$$

$$= 0.1246 \text{ nm}.$$

31. $\dfrac{r_{Na^+}}{r_{Na^-}} = 0.55 \quad$ or $\quad 1 + \dfrac{r_{Na^+}}{r_{Cl^-}} = 1.55 \quad$ or $\quad \dfrac{r_{Na^+} + r_{Cl^-}}{r_{Cl^-}} = 1.55.$

Given that $\dfrac{r_{Na^+}}{r_{K^+}} = 0.74$

or $\quad \dfrac{r_{K^+}}{r_{Na^+}} = \dfrac{r_{K^+}}{r_{Na^+}/0.55} = \dfrac{0.55}{r_{Na^+}/r_{K^+}} = \dfrac{0.55}{0.74} = 0.74$

or $\quad 1 + \dfrac{r_{K^+}}{r_{Na^+}} = 1 + 0.74.$

$$\frac{r_{K^+} + r_{Cl^-}}{r_{Na^+} + r_{Cl^-}} = \frac{1.74}{1.55}$$

or $$\frac{a_{KCl}/2}{a_{NaCl}/2} = \frac{1.74}{1.55} = 1.122$$

32. For a cubic crystal,

$$d_{hKl} = \frac{a}{\sqrt{h^2 + k^2 + l^2}} \tag{1}$$

where a = latticeparameter

hkl = Miller indices.

Use Bragg's equation

$$n\lambda = 2d_{hkl} \sin\theta.$$

For first-order reflection, $n = 1$.

$$\therefore \quad \lambda = 2d_{hkl} \sin\theta. \tag{2}$$

From Equations (1) and (2),

$$\sin\theta = \frac{\lambda}{2a}(k^2 + k^2 + l^2)^{½}.$$

36. Solid CO_2 adopts a rock-salt structure.

39. The inverse spinel is represented by the formula $B(AB)O_4$ containing A^{2+} and B^{3+} ions.

45. In a hexagonal lattice,

$$\alpha = \beta = 90°; \gamma = 120°.$$

48. Apply the radius ratio rules.

50. Consider the positions where a cation can be surrounded by four atoms.

53. Miller indices $hkl = \frac{a}{\frac{a}{2}}, \frac{b}{\frac{b}{2}}, \frac{c}{\infty c} = (2, 2, 0)$

54. $d_{hkl} = \dfrac{a}{\sqrt{h^2 + k^2 + l^2}} \Rightarrow d_{110} = \dfrac{a}{\sqrt{1^2 + 1^2 + 1^2}} = \dfrac{a}{\sqrt{3}}$.

$$d_{11} = \frac{318}{\sqrt{3}} = 184 \text{ pm}.$$

57. $V_1 = (400 \times 10^{-12} \text{ m})^3 = 64 \times 10^{-30} \text{ m}^3$.

$$V_2 = \frac{\text{mass}}{\text{density}} = \frac{0.015 \text{ kg}}{7.5 \times 10^{-3} \text{ m}^{-3}}$$

$$= 2 \times 10^{-6} \text{ m}^3,$$

where V_1 is the volume of the unit cell and V_2 that of the metal sample.

$$\therefore \text{ no. of unit cells} = \frac{2 \times 10^{-6}\ \text{m}^3}{64 \times 10^{-30}\ \text{m}^3} = 3.125 \times 10^{22}.$$

58. $\dfrac{d_{\text{KCl}}}{d_{\text{NaCl}}} = \left(\dfrac{37.46}{27.94}\right)^{1/3} = 1.116.$

59. Apply the radius ratio rules.

60. The volume of a lattice is given by

$$V = abc(1 - \cos^2\alpha - \cos^2\beta - \cos^2\gamma - 2\cos\alpha\cos\beta\cos\gamma)^{1/2}.$$

$$V_{\text{tetragonal}} = a^2c \ \ (\text{because } a = b \neq c, \alpha = \beta = \gamma = 90°).$$

$$V_{\text{hexagonal}} = a^2c \times \frac{\sqrt{3}}{2} \ (\text{because } a = b \neq c, \alpha = \beta = 90°, \gamma = 120°).$$

$$\therefore \quad \frac{V_{\text{tetragonal}}}{V_{\text{hexagonal}}} = \frac{a^2c \times 2}{a^2c\sqrt{3}} = \frac{2}{\sqrt{3}}.$$

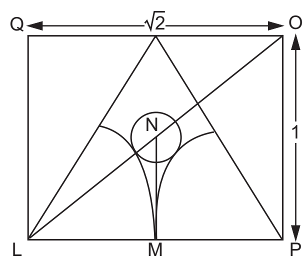
62. Volume $= a^3 = (400 \times 10^{-12}\ \text{m})^3 = 64 \times 10^{-24}\ \text{cm}^3$

$V_{\text{total}} = VN_{\text{A}} = 64 \times 10^{-24} \times 6.02 \times 10^{23} \approx 38.4.$

Molar volume $= \dfrac{1}{4} V_{\text{total}} = \dfrac{1}{4} \times 38.4 = 9.6$ mL.

63. Draw the structure.

69. The required tetrahedron is shown in the figure. The right triangle LMN is similar to the right triangle LPO.



$$\therefore \quad \frac{\text{LM}}{\text{LN}} = \frac{\text{LP}}{\text{LO}} = \sqrt{\frac{2}{\sqrt{3}}}.$$

If r is the radius of the sphere representing the void and R the radius of the spheres in a closest-packed structure then

$$\frac{\text{LM}}{\text{LN}} = \frac{R}{R + r} = \sqrt{\frac{2}{3}}.$$

$$r = 0.225\ R \Rightarrow \frac{r}{R} = 0.225.$$

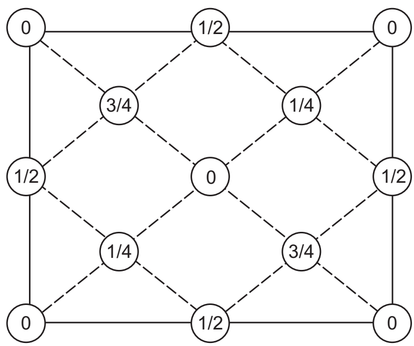
71. The number of octahedral voids (holes) in a close-packed structure is equal to the number of spheres (atoms). Similarly, the number of tetrahedral voids (holes) in a close-packed structure is twice the number of spheres (atoms).

72. For an fcc or a ccp structure, the coordination number is 12 and for a bcc structure the coordination number is 8.

81. The number of octahedral voids belonging to one sphere is given by the following ratio.

$$\frac{\text{Number of octahedral voids around the sphere}}{\text{Number of spheres around the void}} = \frac{6}{6} = 1.$$

83. The space lattice of diamond is fcc. The primitive basis has two identical atoms at 0, 0, 0 and $\frac{1}{4}, \frac{1}{4}, \frac{1}{4}$ associated with each point of the fcc lattice as shown in the figure.



89. See the hint to Q. 72.

91. The compound has a perovskite structure.

93. Such coordination is exhibited by compounds which have bcc latice structures.

102. Draw the structure and apply radius ratio rules.

103. Normal spinels are represented by formula $\overset{II}{A}\overset{III}{B_2}O_4$.

❑

18

Surface Chemistry and Colloids

• *Type 1* •

Choose the correct option. Only one option is correct.

1. Which of the following statements is incorrect?

(a) Physical adsorption occurs at very low temperature and chemisorption occur at all temperatures.

(b) The magnitude of chemisorption decreases with rise in temperature and physisorption increases with rise in temperature.

(c) Chemisorption is irreversible and physisorption is reversible.

(d) In physisorption, the activation energy of desorption is very low and in chemisorption, the activation energy of desorption is very high.

2. For the adsorption of a gas on a solid, the plot of $\log(x/m)$ versus $\log p$ is linear with slope equal to

(a) k (b) $\log k$ (c) n (d) $\frac{1}{n}$

(where, p = presure of gas, m = mass of the adsorbent, x = mass of the gas adsorbed)

3. Which of the following gas molecules have maximum value of enthalpy of physisorption?

(a) C_2H_6 (b) Ne (c) H_2O (d) H_2

4. Which of the following gas is adsorbed most by activated charcoal?

(a) CO_2 (b) N_2 (c) CH_4 (d) Ar

5. Adsorption is accompanied by the evolution of heat. So according to Le-Chatelier principle the amount of substance adsorbed should

(a) increase with decrease in temperature.

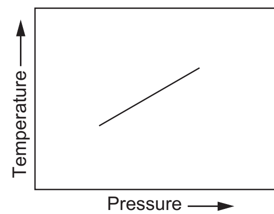
(b) increase with increase in temperature.

(c) decrease with decrease in temperature.
(d) decrease with increase in temperature.

6. In physical adsorption, the gas molecules are held by solid surfaces by
(a) strong chemical forces (b) van der Waals forces
(c) metallic bonds (d) gravitational forces

7. At low pressure, the fraction of the surface covered follows
(a) zero-order reaction (b) second-order reaction
(c) first-order reaction (d) fractional order

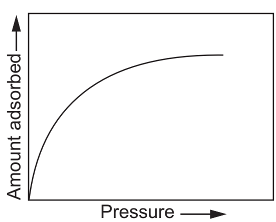
8. The curve showing the variation of pressure with temperature for a given amount of adsoption is called

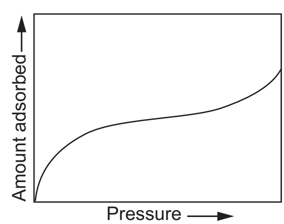


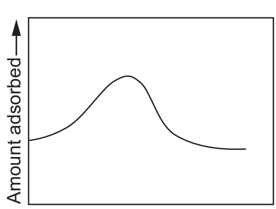
(a) adsorption isobar
(b) adsorption isotherm
(c) adsorption isostere
(d) adsorption isochore

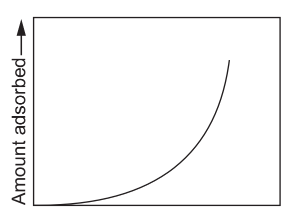
9. At high pressure, the entire surface gets covered by a monomolecular layer of the gas follows
(a) three-halved order (b) second-order
(c) first-order (d) zero-order

10. Which of the following curves do not correspond to adsorption isotherms?

(a)


(b)


(c)


(d)


11. Which of the following statements is correct?
(a) Physical adsorption is a multilayer phenomena.
(b) Chemical adsorption is the function of adsorbate only.

(c) The extent of physical adsorption increases with increase in pressure of the adsorbate and ultimately attain a limited value.

(d) Physical adsorption is a monolayer phenomena.

12. Indicate the correct statement.

(a) In chemisorption, there is no disruption of bonding in an adsorbed molecule.

(b) The rate of decomposition of the substance adsorbed on a surface depends on the surface coverage.

(c) In heterogeneous catalytic reaction no surface reaction occurs.

(d) Increase in surface area of catalyst reduces the surface phase reactions.

13. Which of the following statements is incorrect?

(a) Adsorption always leads to a decrease in enthalpy and entropy of the system.

(b) Adsorption arises due to unsaturation of valence forces of atoms or molecules on the surface.

(c) Adsorption increases with rise in the temperature.

(d) Adsorption decreases the surface energy.

14. During adsorption

(a) $T\Delta S$ is positive (b) $\Delta H - T\Delta S$ is negative

(c) ΔH is positive (d) $T\Delta S$ and ΔG become zero

15. Which of the following statements is not correct?

(a) Decrease of temperature and increase of pressure, both tend to cause increase in the magnitude of adsorption of a gas on a solid.

(b) The easily liquefiable gases adsorb more on solid.

(c) Greater the surface area per unit mass of the adsorbent, the greater is its capacity of adsorption.

(d) None of these.

16. The range of colloidal dispersions lie between

(a) less than 1 mμ (b) greater than 0.5 μ

(c) 0.5 μ to 1 mμ (d) none of these

17. If the disperse phase and the dispersion medium both are liquid, the colloidal solution is classified as

(a) emulsion (b) foam

(c) gel (d) supercooled liquid

18. Separation of colloidal particles from those of molecular dimension by means of electric current is known as

(a) Electroosmosis (b) Electrophoresis

(c) Electrodialysis (d) Electrolysis

19. The Brownian movement is due to

(a) enthalpy change during the formation of colloids

(b) attractive forces between the colloidal particles and the molecules of dispersion medium

(c) the impact of moelcules of the dispersion medium on the colloidal particles

(d) the movement of positively charged colloidal particle to negatively charged particle

20. Gold number is the index for

(a) protective power of lyophilic colloid

(b) purity of gold

(c) metallic gold

(d) electroplated gold

21. Lyophobic colloids are

(a) reversible colloid (b) irreversible colloid

(c) protective colloids (d) proteins

22. The critical micelle concentration (CMC) is

(a) the concentration at which micellization starts

(b) the concentration at which the true solution is formed

(c) the concentration at which one molar electrolyte is present per 1000 g of the solution

(d) the concentration at which $\Delta H = 0$

23. Which type of molecules form micelles?

(a) Nonpolar molecules (b) Polar molecules

(c) Surfactant molecules (d) Salt of weak acid and weak base

24. Fog is a colloidal solution of

(a) liquid particles dispersed in gas

(b) gaseous particles dispersed in a liquid

(c) solid particles dispersed in a liquid

(d) solid particles dispersed in gas

25. A gel is

(a) a liquid mass of a lyophilic sol in which all the dispersion medium has penetrated into the sol particles.

(b) like an emulsion which is stabilized by adding emulsifying agent

(c) a semirigid mass of a lyophobic sol in which all the dispersion medium has penetrated into the sol particles

(d) a semirigid mass of a lyophilic sol in which all the dispersion medium has penetrated into the sol particles.

26. Addition of lyophilic soln. to the emulsion, forms
- (a) a protective film around the dispersed phase
- (b) a protective film around the dispersion medium
- (c) an aerosol
- (d) true solution

27. During Micelle formation
- (a) $\Delta H = +ve$ $\Delta S = +ve$
- (b) $\Delta H = -ve$ $\Delta S = -ve$
- (c) $\Delta H = -ve$ $\Delta S = +ve$
- (d) $\Delta H = +ve$ $\Delta S = -ve$

28. Micelles form only
- (a) below the critical micelle concentration (CMC) and below the krafft temperature (KT)
- (b) above the CMC and below the KT
- (c) above the CMC and above the KT
- (d) below the CMC and above the KT

29. Micelles are
- (a) emulsion cum gel
- (b) associated colloids
- (c) adsorbed catalysts
- (d) ideal solutions

30. Which of the following ions have minimum value of flocculating power?
- (a) PO_4^{3-}
- (b) SO_4^{2-}
- (c) SO_3^{2-}
- (d) NO_3^-

31. The isoelectric-point of a colloidally dispersed material is the pH value at which
- (a) the dispersed phase migrate in an electric field
- (b) the dispersed phase does not migrate in an electric field
- (c) the dispersed phase has pH equal to 7
- (d) the dispersed phase has pH equal to zero

32. Which of the following statements is incorrect?
- (a) Emulsions are prepared by shaking two liquid components, say oil and water and adding some emulsifying agent.
- (b) Water-in-oil emulsions are formed when the emulsifying agent at the interface is chiefly in the water phase.
- (c) Water-in-oil emulsions are formed when the emulsifying agent at the interface is chiefly in the oil phase.
- (d) Gems and gels mixed together to give emulsion.

33. Blue colour of the sky and red colour of the sunsets are due to
(a) scattering of light from the sun
(b) scattering of light from particles of dust in the atmosphere
(c) refraction of blue light by impurities in sea water
(d) scattering of light due to ozone layer.

34. The arsenious soln. is negatively charged. The maximum power of precipitating it, is in
(a) Na_2SO_4 (b) Na_3PO_4
(c) $AlCl_3$ (d) $Mg(NO_3)_2$

35. Which of the following statements is correct for Tyndall effect?
(a) Scattering and polarizing of light by small suspended particles is called Tyndall effect.
(b) Tyndall effect of colloidal particles is due to dispersion of light.
(c) Tyndall effect is due to refraction of light.
(d) Zig-zag motion of suspended particles.

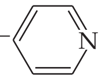
36. The coagulating power of an effective ion carrying the charge opposite to the sol particles is given by
(a) Brownian movement (b) Gold number
(c) Tyndall effect (d) Hardy-Schulz law

37. Milk is an emulsion in which
(a) a liquid is dispersed in a liquid
(b) a solid is dispersed in a liquid
(c) a gas is dispersed in a liquid
(d) lactose is dispersed in a liquid

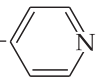
38. Lyophilic solutions are more stable than lyophobic solution because
(a) the colloidal particles have positive charge
(b) the colloidal particles have negative charge
(c) the colloidal particles are solvated
(d) there is strong electrostatic repulsions between the negatively charged colloidal particles

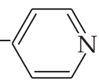
39. Hardy-Schulz law states that
(a) larger the size of the coagulating ions, greater its coagulating power, having opposite sign of solution
(b) solution must have zero gold number
(c) disperse phase and dispersion medium must be of the same sign
(d) micelles coagulate in presence of surfactants

40. Cationic, anionic and non-ionogenic surfactants are respectively

(a) $C_{17}H_{35}CO_2Na$, $C_{16}H_{33}$—  —Cl and $C_nH_{2n+1}(OCH_2CH_2)_nOH$

(b) $C_nH_{2n}(OCH_2CH_2)_mOH$, $C_{15}H_{31}CO_2Na$ and $C_{18}H_{37}\{\overset{+}{N}H_3\}Cl^-$

(c) $C_{16}H_{33}$—  Cl, $C_{17}H_{35}CO_2Na$ and $C_nH_{2n+1}(OCH_2CH_2)_mOH$

(d) $C_{18}H_{37}\overset{+}{N}H_3Cl^-$, $C_{16}H_{33}$—  —Cl and $C_nH_{2n+1}OH$

41. Peptization involves

(a) precipitation of colloidal particles

(b) disintegration of colloidal aggregates

(c) evaporation of dispersion medium

(d) impact of molecules of the dispersion medium on the colloidal particles

42. A freshly prepared $Fe(OH)_3$ precipitate is peptized by adding $FeCl_3$ solution. The charge on the colloidal particles is due to preferential adsorption of

(a) Br^- ion (b) Fe^{3+} ion (c) OH^- ion (d) Ba^{2+} ion

43. Which of the following is not the property of hydrophilic solutions?

(a) High concentration of dispersed phase can be easily obtained.

(b) Coagulation is reversible.

(c) Viscosity and surface tension are nearly the same as that of water.

(d) The charge of the particle depends on the pH of the medium and it may be positive, negative or zero.

• Type 2 •

Choose the correct options. More than one option is correct.

44. At CMC, the surfactant molecules undergoes

(a) dissociation (b) aggregation

(c) micelle formation (d) all of these

45. Emulsions are normally prepared by shaking vigorously the two components together with some kinds of emulsifying agent to stabilize the product. The emulsifying agents may be a

(a) soap (b) surfactant
(c) lyophilic solution (d) none of these

46. Surfactant molecules or ions can cluster together as *micelles*, which
(a) are colloid-sized clusters of molecules
(b) due to their hydrophobic tails tend to congregate
(c) due to their hydrophilic heads provide protection
(d) none of these

47. Micelle systems are used in
(a) detergents (b) magnetic separation process
(c) petroleum recovery (d) all of these

48. Which of the following statements are correct?
(a) Non-ionic surfactant molecules cluster together in clumps
(b) Ionic surfactants tend to disrupt by electrostatic repulsions between head groups
(c) Micelles look like flattened-spherical structure at CMC
(d) All of these

49. Emulsion can be destroyed by
(a) the addition of an emulsifier which tends to form an emulsion of the same type
(b) electrophoresis with a high potential
(c) freezing
(d) all of these

50. Which of the following statements is correct?
(a) If the mutual affinity between the dispersed phase and the dispersion medium is small, the system will be lyophobic.
(b) If the mutual affinity between the dispersed phase and dispersion medium is great, the system will be lyophilic.
(c) In a system, when water is the dispersion medium, the system may be hydrophobic or hydorphilic.
(d) None of these

51. In which of the following reactions colloids are prepared by the double decomposition method?
(a) $2H_3AsO_4 + 3H_2S \rightarrow \underset{\text{sol}}{As_2S_3} + 6H_2O$
(b) $3K_4[Fe(CN)_6] + 4FeCl_3 \rightarrow \underset{\text{sol}}{Fe_4[Fe(CN)_6]_3} + 12\ KCl$
(c) $Hg(CN)_2 + H_2S \rightarrow \underset{\text{sol}}{HgS} + 2HCN$
(d) All of these

52. Colloidal solution is prepared by
(a) reduction method
(b) dissociation method
(c) hydrolysis method
(d) none of these

53. Which of the following statements is correct for electrophoresis?
(a) Colloids are uncharged particles and do not migrate towards the electrodes when electric field is applied.
(b) In electrophoresis, solution migrates either to the anode or to the cathode depending on the positively or negatively charged solution.
(c) Electrophoresis is a useful method for finding the charge of a solution.
(d) All of these.

Answers

1. b	**2.** d	**3.** c	**4.** a	**5.** a
6. b	**7.** c	**8.** c	**9.** d	**10.** c
11. a	**12.** b	**13.** c	**14.** b	**15.** d
16. c	**17.** a	**18.** b	**19.** c	**20.** a
21. b	**22.** a	**23.** c	**24.** a	**25.** d
26. a	**27.** a	**28.** c	**29.** b	**30.** a
31. b	**32.** d	**33.** b	**34.** c	**35.** a
36. d	**37.** a	**38.** c	**39.** a	**40.** c
41. b	**42.** b	**43.** c	**44.** b, c	**45.** a, b, c
46. a, b, c	**47.** a, c	**48.** a, b, c, d	**49.** b, c	**50.** a, b, c
51. a, b, c, d	**52.** a, b, c	**53.** b, c		

Hints to More Difficult Problems

2. Apply $x/m = Kp^{1/n}$

3. H_2O can be liquefied easily

6. Weak intermolecular forces

12. Greater area of the surface

14. Spontaneous reaction

19. Zig-zag motion of suspended particles

21. Rest are lyophilic

22. It is the minimum concentration at which surfactant molecules undergo aggregation.

24. Fog is liquid dispersed in gas, a class of colloidal system

26. Surface phase reaction

30. Greater magnitude of charge

32. Gems are solid and gels are semi-solid. This mixture will not form emulsion.

34. Greater charge on Al

38. Form stable colloids due to solvation

42. Solution particle adsorbs common ion present in the medium.

43. Solvent hating character.

44. All are the same processes.

❑

19

Assertion–Reason Questions

These questions consist of an *assertion* in column 1 and a *reason* in column 2. Use the following key to choose the appropriate answer.

(a) If the *assertion* as well as the *reason* are correct, and the *reason* is the correct explanation of the *assertion*.

(b) If the *assertion* as well as the *reason* are correct, but the *reason* is not the correct explanation of the *assertion*.

(c) If the *assertion* is correct but the *reason* is not.

(d) If the *assertion* is incorrect but the *reason* is correct.

	Assertion	***Reason***
1.	We cannot measure position and momentum with arbitrary precision.	There is a deep fundamental flaw in the very measuring process.
2.	Bohr's theory gave reasonably correct spectroscopic results for hydrogenic species even though it used classical mechanics for its derivation.	The semiclassical approach is valid to some extent for spectroscopic derivations in the context of hydrogenic species.
3.	An ideal gas follows a hyperbolic relation between p and V in isothermal conditions.	The percentage change in p added to that in V equals zero (T = constant).
4.	Spectral wave numbers bear a linear relationship with the square of the principal quantum number.	This is a direct consequence of Bohr's energy condition.
5.	All collisions between reactants do not yield the desired product.	An activation complex can form only when the required steric and energy conditions are met.

	Assertion	Reason
6.	N_2F_2 never obeys the ideal gas law.	It has a very high viscosity.
7.	The *T-P* curve in the Joule–Thomson experiment does not represent an isenthalpic process.	The enthalpy remains constant during the entire Joule–Thomson expansion.
8.	By appropriately choosing a catalyst, we can significantly increase yield.	Catalysts increase the rate constant to a large extent.
9.	Alpha-emission is classically forbidden.	It involves quantum tunnelling.
10.	A photochemically induced reaction does not yield products based on the equilibrium constant.	A photochemical energy distribution is not a classical Boltzmann distribution.
11.	The nucleus of gold is stable even though there is a very strong Coulomb repulsion between the protons.	The inverse square Coulomb force is exactly balanced by another inverse square force which is very powerful—the nuclear force.
12.	For every process in an isolated system, the entropy increases.	$\Delta S \geq \int \delta q_r / T$
13.	An ideal Carnot cycle has 100% efficiency.	All steps of the Carnot cycle are reversible, and are assumed to be frictionless.
14.	Lead is most effective in shielding radiation.	It is very stable, and many radioactive reactions finally yield lead.
15.	Henry's law and Raoult's law are not independent, i.e., one can be derived from the other.	The partial pressure is directly proportional to the mole fraction of the concerned species for ideal solutions.
16.	A salt bridge is essential for the working of a galvanic cell.	A salt bridge greatly enhances ionic mobility, μ_{ion}.
17.	Electronic penetration is observed in almost all multielectronic species.	The radial distribution function shows multiple peaks of varying amplitude.
18.	H^+ and OH^- react very rapidly to yield H_2O.	The equilibrium constant K_{eq} for the reaction is very high ($\sim 10^{15}$).
19.	K-shell electron capture is detected by analysing the wavelength of the X-ray photon emitted.	The wavelength of the X-ray photon is characteristic of the daughter element and not the parent element.

	Assertion	Reason
20.	Tin-plating of iron is not recommended as a guard against corrosion.	Once the surface of the tin-plating is scratched, there is rapid oxidation of iron because of the formation of an electrolytic couple.
21.	A fuel cell gives much more energy than a conventional Galvanic cell.	The exchange current density of a fuel cell is very low.
22.	Activity is not an experimentally measurable quantity.	Activity is just a type of effective mole fraction and $a = p/p^0$.
23.	Bond dissociation energy refers to energy changes during the gaseous state.	Bonds cannot break in the liquid and solid phases.
24.	In deriving the Nernst equation, we directly equate electric work with change in free energy.	This is just an approximation; we neglect the *P-V* work of the system.
25.	The term "molecularity of the overall reaction" is meaningless.	Molecularity refers to the order of the rate-determining step.
26.	The Zeeman effect could not be predicted by the Bohr model.	The Zeeman effect is the result of the interaction of the magnetic field B and the quantized angular momentum, L.
27.	A reversible process is associated with maximum work.	In a reversible expansion the system expands/contracts against maximum possible pressure.
28.	The entropy of a system always increases after a spontaneous process.	The Clausius inequality rule states that $\int_{\text{cycle}} \delta q/T \le \Delta S$ for any process.
29.	The van't Hoff equation in the conventional form cannot be used for macromolecular solutes.	The van't Hoff equation is the first term of the virial-like equation $\Pi = [B]\,RT\,\{1 + B[B] + \ldots)$ where $[B] = c/M$ (c = mass concentration, M = molecular mass, B = virial coefficient).
30.	The volume of a hexagonal ice lattice is $a^2c \sin 120°$.	$a = b \neq c;\ \alpha = \beta = 90°,\ \gamma = 60°$
31.	Phenolphthalein is used as an indicator during the titration of oxalic acid against sodium hydroxide.	The pH range of phenolphthalein is from 8 to 9.6.

32.	CH_3NO_2 is less polar than CH_3NH_2.	In CH_3NO_2, the formal charge on N is +1.
33.	The reaction of isopropyl alcohol with HF and that with HCl are endothermic and exothermic respectively.	$\Delta H°$ is negative in the former case and positive in the latter.
34.	In the Nernst equation, the stoichiometric coefficients of a balanced chemical reaction do not matter.	The change in the form of K is taken care of by the premultiplying factor of n (number of moles).
35.	The efficiency of a Carnot cycle is independent on the working substance employed.	All irreversible engines are necessarily less efficient than the Carnot engine.
36.	ΔH is not always equal to $C_p \Delta T$.	C_p is a polynomial function of temperature.
37.	A catalyst can be used almost infinite times for a particular chemical reaction	A catalyst is not consumed during a chemical reaction.
38.	The NaCl molecule has 8 corners and 12 edges shared.	NaCl has a 6 : 6 coordination system.
39.	The standard electrode potential of alkali metals are uniform and close to 3.0 V.	All alkali metals have very low hydration energy.
40.	Quasi-crystals form when certain molten alloys cool very slowly.	Quasi-crystals have short-range as well as long-range order in their arrangements.

Answers

1. c	**2.** c	**3.** b	**4.** d	**5.** a
6. c	**7.** b	**8.** d	**9.** a	**10.** a
11. c	**12.** d	**13.** c	**14.** b	**15.** b
16. c	**17.** a	**18.** b	**19.** b	**20.** a
21. c	**22.** d	**23.** a	**24.** d	**25.** c
26. b	**27.** a	**28.** c	**29.** a	**30.** c
31. a	**32.** d	**33.** c	**34.** a	**35.** b
36. a	**37.** d	**38.** d	**39.** c	**40.** d

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20

Matching-Type Questions (Chapterwise)

Atomic Structure—I

1. Energy of a massless particle	(a) $a^2 + b^2$
2. Work function	(b) Four
3. $\psi\psi^*$	(c) $E = pc$
4. Number of lobes in a 3d orbital other than $3d_{z^2}$	(d) Connected to orbital motion
5. Energy and angular momentum	(e) $\vec{L}$
6. Mutual repulsion of atomic electrons	(f) Minimum energy needed to liberate an electron from the surface of a metal
7. Mass times velocity times radius	(g) Quanta
8. The frequency distribution of the radiation emitted from a black body	(h) $\int_{x_1}^{x_2} \lvert\psi\rvert^2 \, dx$
9. Probability of finding an electron in a given region	(i) Hund rule
10. Black-body radiation	(j) Temperature-dependent

Atomic Structure—II

1. Pauli exclusion principle	(a) Lower energy state
2. Nodal plane	(b) $\sqrt{l(l+1)}\,\hbar$
3. Number of angular nodes	(c) $\frac{\sqrt{3}}{2}\hbar$
4. Number of radial nodes	(d) Higher energy state

5. The $3d_{z^2}$ orbital looks like a cone having angles	(e) The plane dividing regions of opposite sign of the wave function
6. Magnitude of the spin angular momentum of an electron	(f) $R_\infty hc$
7. Magnitude of the orbital angular momentum of an electron	(g) 55° and 125°
8. Bound-state energy	(h) l
9. Unbound-state energy	(i) $n - l - 1$
10. Ionization energy	(j) Explained by determinant

Nuclear Chemistry

1. ^{14}C	(a) Gamma rays
2. Survival probability of a radioactive nucleus	(b) K-electron capture
3. Breeder reactor	(c) Neptunium series
4. De-excitation of nuclei	(d) $N_0 - N_0e^{-\lambda t}$
5. Addition of an electron and a positron	(e) Shortest half-life
6. $^{241}Pu \rightarrow {}^{209}Bi$	(f) Proton–proton cycle
7. Neutron decay	(g) Annihilation
8. Nuclear fusion	(h) Production of the same fissile material as it uses
9. Emission of β^+	(i) β^- emitter
10. ^{212}Po	(j) Antineutrino

Chemical Bonding

1. Maximum number of carbon atoms arranged linearly in the molecule $CH_3C{\equiv}CH_2{=}CH_2$	(a) 12 pentagons and 20 hexagons
2. Number of π bonds in hex-1,3-diene-5-yne	(b) Graphite
3. A C_{60} molecule has	(c) Neopentane
4. Species having zero dipole moment	(d) ClO_2

5. All carbon atoms are sp^2-hybridized	(e) An electron is removed from the π^* MO
6. Intramolecular hydrogen bonding	(f) IF_6
7. Species not obeying the octet rule	(g) An electron is removed from the σ MO
8. Expanded octet structure	(h) $Ni(CN)_4^{2-}$
9. $O_2 \rightarrow O_2^+$	(i) B_2
10. $N_2 \rightarrow N_2^+$	(j) Four
11. Species having two unpaired electrons	(k) I_3^-
12. Linear structure	(l) C_{60}
	(m) 2-Nitrophenol
	(n) Ethyl acetoacetate (enol form)
	(o) PCl_5
	(p) 20 pentagons and 18 hexagons

The Gaseous State

1. No gas can liquefy above T_c	(a) Supercritical fluid
2. Boyle temperature	(b) $\dfrac{1}{C_{p,\mathrm{m}}}\left(\dfrac{2a}{RT}-b\right)$
3. Inversion temperature	(c) Unrealistic oscillations in the van der Waals isotherms
4. Van der Waals loops	(d) The equal-area rule for the replacement of the van der Waals loops by horizontal straight lines
5. Maxwell construction	(e) The temperature at which the Joule–Thomson coefficient changes its sign
6. Graham's law of diffusion	(f) The temperature at which $\dfrac{dZ}{dp}=0$
7. Dense fluid phase above T_c and p_c	(g) Molecules have high thermal energy, and intermolecular forces are not powerful enough to make molecules stick together
8. Joule–Thomson coefficient	(h) $\dfrac{u^2_{\mathrm{rms}\,1}}{u^2_{\mathrm{rms}\,2}}=\dfrac{M_2}{M_1}$

The Liquid State
(Viscosity and Surface Tension)

1. Superfluid helium	(a) $\frac{dT}{dz}$
2. Viscosity	(b) $-\eta \frac{dv_x}{dz}$
3. Newtonian flow	(c) $\frac{dv}{dz}$
4. Coefficient of viscosity	(d) Migration of linear momentum down a velocity gradient
5. Energy flux	(e) Flow of liquid through a series of layers
6. Momentum of flux	(f) A liquid phase that flows without viscosity

Oxidation–Reduction

1. $Cr_2O_7^{2-} \rightarrow CrO_5$	(a) $\frac{M}{5}$
2. $BrO_3^- + Br^- + H^+ \rightarrow Br_2$	(b) $\frac{M}{1}$
3. $I^- + I_2 \rightarrow I_3^-$	(c) $\frac{M}{3}$
4. MnO_4^- in acidic medium	(d) 24 electrons
5. MnO_4^- in alkaline medium	(e) $-\frac{1}{3}$
6. MnO_4^- in neutral or slightly alkaline medium	(f) +2, +4
7. $2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$	(g) Change in oxidation number of the metal is zero
8. Oxidation number(s) of Fe in Fe_3O_4	(h) Change in oxidation number of carbon is one
9. Oxidation number(s) of Pb in Pb_3O_4	(i) Disproportionation reaction
10. $Fe_3O_4 + Al \rightarrow Al_2O_3 + Fe$	(j) +2, +3

Modern Concepts of Acids and Bases

1. Species having no conjugate base	(a) $Be(OH)_2$
2. Species that can act neither as a conjugate acid nor as a conjugate base	(b) N_2H_4

3. Species that can act both as a conjugate acid and a conjugate base	(c) $BeCl_2$
4. Species that can act both as a Brønsted base and a Lewis base	(d) Base
5. Monoprotic acid(s)	(e) Acid
6. Compound having amphoteric character	(f) $Ca(HCO_3)_2$
7. Compound that does not act as a Lewis acid	(g) HCO_3^-
8. Protophilic solvent	(h) C_6H_6
9. In a nitrating mixture, HNO_3 acts as a(n)	(i) SO_4^{2-}
10. Salts do not exist in the solid state	(j) $:CH_2$
	(k) $:CN^-$
	(l) H_3BO_3 and H_3PO_2

Volumetric Analysis
(Titration)

1. Titration of $FeSO_4$ versus $KMnO_4$	(a) Phenolphthalein indicator
2. Titration of a mixture of Na_2CO_3 and $NaHCO_3$	(b) Gravimetrically
3. Titration of $Na_2C_2O_4$ versus NaOH	(c) No indicator
4. Titration of boric acid and NaOH solution	(d) Phenolphthalein and methyl orange indicators
5. Titration of $CuSO_4$ solution and $Na_2S_2O_3$ solution	(e) K_2CrO_4 indicator
6. Titration of Mohr salt versus $K_2Cr_2O_7$	(f) Acid–base and redox titration
7. Titration of NH_2OH versus $KMnO_4$	(g) Barium diphenylamine sulphonate indicator
8. Estimation of $CuSO_4$ by producing CuSCN	(h) Methyl red indicator
9. Titration of $AgNO_3$ versus NaCl	(i) Starch solution indicator
10. Estimation of a mixture of $Na_2C_2O_4$ and $NaHC_2O_4$ versus a strong base	(j) Methyl orange indicator

Thermodynamics and Thermochemistry

1. Clausius inequality	(a) Perfect differential
2. Work done in adiabatic process	(b) Zero when $T \to 0$
3. Work done in isothermal reversible expansion	(c) Imperfect differential
4. Entropy of all perfectly crystalline substances	(d) $-p$
5. Criteria of spontaneity	(e) $dS \geq \frac{dq}{T}$
6. Spontaneous process	(f) $\Delta_{fus}H^\circ - \Delta_{vap}H^\circ$
7. $\Delta_{sub}H^\circ$	(g) $dS_{U,V} \geq 0$ and $dU_{S,V} \leq 0$
8. dq_{rev}	(h) $\frac{p_1V_1 - p_2V_2}{\gamma - 1}$
9. $\frac{dq_{rev}}{T}$	(i) $-nRT \ln \frac{V_2}{V_1}$
10. $\left.\frac{\partial U}{\partial V}\right]_S$	(j) $\Delta S > 0$
	(k) $\Delta S < 1$
	(l) $\Delta_{fus}H^\circ + \Delta_{vap}H^\circ$

Chemical Equilibrium

1. Reaction quotient	(a) $\left(\frac{1}{1+4p/K}\right)^{1/2}$
2. Equilibrium constant (K_{eq})	(b) High temperature and low pressure will favour the formation of the product
3. $\left.\frac{\partial K}{\partial p}\right]_T$	(c) Low temperatue and high pressure will favour the formation of the product
4. Extent of dissociation for $A(g) \rightleftharpoons 2B(g)$	(d) $\prod^{J} a_J^{\nu_J}$
5. $N_2O_4(g) \rightleftharpoons 2NO_2(g)$	(e) Zero
6. $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$	(f) $\left(\prod^{J} a_J^{\nu_J}\right)_{eq}$

Chemical Kinetics

1. Acidic hydrolysis of ethyl acetate	(a) mol L^{-1} s^{-1}
2. Alkaline hydrolysis of ethyl acetate	(b) Studied by polarimeter
3. Unit of *A* (Arrhenius parameter)	(c) Second-order reaction
4. Time required for the concentration of a reactant to fall to $1/e$ of its initial value	(d) Saponification
5. Reciprocal of rate constant	(e) Straight line
6. Decomposition of CH_3CHO	(f) First-order kinetics
7. $S_2O_8^{2-} + 2I^- \rightleftharpoons 2SO_4^{2-} + I_2$	(g) Same as that of rate constant
8. Unit of rate constant of zero-order reactions	(h) Time constant
9. Inversion of cane sugar	(i) Fractional order
10. Plot of $t_{1/2}$ versus concentration	(j) Half-life constant
	(k) Second-order kinetics
	(l) Third-order kinetics

Ionic Equilibrium

1. Autoprotolysis constant	(a) Boric acid and borax
2. The pH of 0.1-M HA ($K_a = 10^{-5}$ mol L^{-1})	(b) 1.0
3. The pH range 6.8–9.2	(c) Two buffers
4. The pH of 0.1-M NH_4Ac is calcualted by the equation	(d) $pH = pK_a + \log \frac{[salt]}{[base]}$
5. Sodium tetraborate in water	(e) 3.0
6. The pH of a mixture of 0.1 mol CH_3NH_2 ($K_b = 5 \times 10^{-4}$ mol L^{-1}) and 0.08 mol HCl	(f) Three buffers
7. The pH of a mixture of 75 mL of a 0.2-N HCl solution and 25 mL of a 0.2-N NaOH solution	(g) Decrease in solubility
8. Effectiveness of a buffer	(h) $a_{H_3O^+} a_{OH^-}$
9. Selection of indicators is based on	(i) Alkaline

10. Addition of KBr to AgBr	(j) 10.1
11. H_3PO_4 can have	(k) Buffer capacity
	(l) pK_{In}
12. The pH value of a 0.1-M NH_4Cl solution is determined by using the equation	(m) $pH = \frac{1}{2}pK_w + \frac{1}{2}pK_a + \frac{1}{2}\log c$
	(n) $pH = \frac{1}{2}pK_w - \frac{1}{2}pK_a - \frac{1}{2}pK_b$
	(o) Increase in solubility
	(p) $pH = \frac{1}{2}pK_w - \frac{1}{2}pK_b + \frac{1}{2}\log c$

Electrochemistry

1. Electrochemical cell	(a) $\frac{NE°F}{2.303RT}$
2. Electrolytic cell	(b) Action potential
3. Electrolyte-concentration cell	(c) Electrochemical process
4. Electrode-concentration cell	(d) Acidic cell
5. $\log K$	(e) $\frac{dE°}{dT}$
6. The p.d. across the membrane of a neurone when a signal is propagating	(f) Kohlrausch's law
7. Rusting of iron	(g) Law of independent migration of ions
8. Weak electrolytes	(h) Electrodes have different concentrations
9. Strong electrolytes	(i) $\frac{\Delta S°}{ZF}$
10. Temperature coefficient of a cell	(j) Not a rechargeable battery
11. Lead storage battery	(k) Nonspontaneous reaction is driven by an external source of current

12. $\Lambda_m = \Lambda_m^\circ - Kc^{1/2}$	(l) Electrolytes have different concentations
	(m) Molar conductance falls sharply to low values as concentration increases
	(n) Molar conductance varies slightly with concentration
	(o) Chemical reactions do electrical work

Colligative Properties of Solutions

1. The vapour pressure of $Na_2CO_3 \cdot 10H_2O$ is greater than the water vapour pressure of the atmosphere	(a) Beckmann method
2. The vapour pressure of $CaCl_2 \cdot 6H_2O$ is lesser than the water vapour pressure of the atmosphere	(b) Complexation
3. Absorption of water vapour from the atmosphere without dissolution	(c) $p = p_A^* p_B^* / p_A^* + (p_B^* - p_A^*) y_A$
4. 10% glucose (w/v) and 10% urea (w/v) solutions are	(d) Positive $\Delta_{mix}H$, $\Delta_{mix}V$ and positive minimum boiling azeotrope
5. Composition of vapour in a binary solution	(e) Negative $\Delta_{mix}H$, $\Delta_{mix}V$ and negative maximum boiling azeotrope
6. Azeotropic mixture	(f) Precipitation
7. The elevation of freezing point takes place during	(g) Boiling without changing
8. During mixing of H_2O and HCl	(h) Effervescence
9. During mixing of H_2O and $CH_3CO_2C_2H_5$	(i) Isotonic solutions
10. Most accurate method for the measurement of molar mass	(j) $y_A = x_A p_A^* / p_B^* + (p_A^* - p_B^*) x_A$
11. 34.2% sucrose (w/v) and 6% urea (w/v) solutions are	(k) $y_A = p_A^* p_B^* / p_A^* + (p_B^* - p_A^*) y_A$

12. Total vapour pressure of a mixture of two binary liquids	(l) Not isotonic solutions
	(m) Landsberger's method
	(n) Deliquescence
	(o) Hygroscopic

Solid-State Chemistry

1. Layer structures	(a) ZnS
2. Materials having the conductivity range 10^{-6}–10^{-4} S m^{-1}	(b) Colours in alkyl halides
3. Supercooled liquid	(c) Body-centred-cubic structures
4. Materials having conductivity range 10^{-10}–10^{-20} S m^{-1}	(d) NaCl
5. Substance having Schottky defects	(e) AgBr
6. Substance having a fluorite structure	(f) Insulators
7. Substance having a rutile structure	(g) Semiconductors
8. Substance having Frenkel defects	(h) Coordination numbers 6, 3
9. Devices that converts electrical energy to mechanical strains and vice versa	(i) Graphite and CdI_2
10. Substance having both Schottky and Frenkel defects	(j) Glass
11. Creation of F-centres	(k) Coordination numbers 8, 4
12. Even value of $h + k + l$	(l) Piezoelectric crystals

Surface Chemistry and Colloids—I

1. Physical adsorption	(a) Synthetic detergents and proteins
2. During adsorption	(b) Multilayer phenomenon
3. Isoelectronic points	(c) Synthetic rubber and vulcanization
4. Chemical adsoption	(d) Freundlich adsopriton isotherm
5. Colloidal electrolytes	(e) Langmuir adsorption isotherm

6. Macromolecular colloids	(f) $\Delta G°$, $\Delta H°$, $\Delta S°$ are negative
7. Plot of log $\frac{x}{m}$ against pressure under low pressure	(g) Monolayer phenomenon
8. Plot of log $\frac{x}{m}$ against pressure under any pressure	(h) No migration of ions
	(i) $\Delta G°$ and $\Delta H°$ are negative, and $\Delta S°$ is positive

Surface Chemistry and Colloids—II

1. Emulsifying agent	(a) Colloid-size clusters of molecules
2. Gel	(b) Surfactant
3. Flocculation	(c) An orderly arrangement of micelles
4. Coagulation	(d) Peptization
5. Schultze–Hardy rule	(e) A semirigid mass of a lyophilic sol having a network structure
6. Micelles	(f) Reversible aggregation of colloidal particles
7. Lyotropic mesomorph	(g) Hydrophobic colloids flocculate most efficiently by ions of opposite charge and high charge number
8. Conversion of solution to sol by adding electrolytes	(h) Irreversible aggregation of colloidal particles

Answers

Atomic Structure—I

1. ↔ c	**2.** ↔ f	**3.** ↔ a	**4.** ↔ b	**5.** ↔ d
6. ↔ i	**7.** ↔ e	**8.** ↔ j	**9.** ↔ h	**10.** ↔ g

Atomic Structure—II

1. ↔ j	**2.** ↔ e	**3.** ↔ h	**4.** ↔ i	**5.** ↔ g
6. ↔ c	**7.** ↔ b	**8.** ↔ a	**9.** ↔ d	**10.** ↔ f

Nuclear Chemistry

1. ↔ i	**2.** ↔ d	**3.** ↔ h	**4.** ↔ a	**5.** ↔ g
6. ↔ c	**7.** ↔ j	**8.** ↔ f	**9.** ↔ b	**10.** ↔ e

Chemical Bonding

1. ↔ j	**2.** ↔ j	**3.** ↔ a	**4.** ↔ c, h	**5.** ↔ b, l
6. ↔ m, n	**7.** ↔ d	**8.** ↔ f, o	**9.** ↔ e	**10.** ↔ g
11. ↔ i	**12.** ↔ k			

The Gaseous State

1. ↔ g	**2.** ↔ f	**3.** ↔ e	**4.** ↔ c	**5.** ↔ d
6. ↔ h	**7.** ↔ a	**8.** ↔ b		

The Liquid State

1. ↔ f	**2.** ↔ d	**3.** ↔ e	**4.** ↔ b	**5.** ↔ a
6. ↔ c				

Oxidation–Reduction

1. ↔ g	**2.** ↔ i	**3.** ↔ e	**4.** ↔ a	**5.** ↔ b
6. ↔ c	**7.** ↔ h	**8.** ↔ j	**9.** ↔ f	**10.** ↔ d

Modern Concepts of Acids and Bases

1. ↔ j	**2.** ↔ i	**3.** ↔ g	**4.** ↔ k	**5.** ↔ l
6. ↔ a	**7.** ↔ c	**8.** ↔ b	**9.** ↔ e	**10.** ↔ g

Volumetric Analysis

1. ↔ c	**2.** ↔ d	**3.** ↔ a	**4.** ↔ h	**5.** ↔ i
6. ↔ g	**7.** ↔ c	**8.** ↔ b	**9.** ↔ e	**10.** ↔ f

Thermodynamics and Thermochemistry

1. ↔ e	**2.** ↔ h	**3.** ↔ i	**4.** ↔ b	**5.** ↔ g
6. ↔ j	**7.** ↔ l	**8.** ↔ a	**9.** ↔ b	**10.** ↔ d

Chemical Equilibrium

1. ↔ d	**2.** ↔ f	**3.** ↔ e	**4.** ↔ a	**5.** ↔ b
6. ↔ c				

Chemical Kinetics

1. ↔ f	**2.** ↔ c, d	**3.** ↔ g	**4.** ↔ h, j	**5.** ↔ h, j
6. ↔ i	**7.** ↔ k	**8.** ↔ a	**9.** ↔ b	**10.** ↔ e

Ionic Equilibrium

1. ↔ h	**2.** ↔ e	**3.** ↔ a	**4.** ↔ n	**5.** ↔ i
6. ↔ j	**7.** ↔ b	**8.** ↔ k	**9.** ↔ l	**10.** ↔ g
11. ↔ f	**12.** ↔ p			

Electrochemistry

1. ↔ o	**2.** ↔ k	**3.** ↔ l	**4.** ↔ h	**5.** ↔ a
6. ↔ b	**7.** ↔ c	**8.** ↔ m	**9.** ↔ n	**10.** ↔ e, i
11. ↔ d	**12.** ↔ g			

Colligative Properties of Solutions

1. ↔ h	**2.** ↔ n	**3.** ↔ o	**4.** ↔ l	**5.** ↔ j
6. ↔ g	**7.** ↔ b	**8.** ↔ e	**9.** ↔ d	**10.** ↔ a
11. ↔ i	**12.** ↔ c			

Solid-State Chemistry

1. ↔ i	**2.** ↔ g	**3.** ↔ j	**4.** ↔ f	**5.** ↔ d
6. ↔ k	**7.** ↔ h	**8.** ↔ a	**9.** ↔ l	**10.** ↔ e
11. ↔ b	**12.** ↔ c			

Surface Chemistry and Colloids—I

1. ↔ g	**2.** ↔ f	**3.** ↔ h	**4.** ↔ b	**5.** ↔ a
6. ↔ c	**7.** ↔ d	**8.** ↔ e		

Surface Chemistry and Colloids—II

1. ↔ b	**2.** ↔ e	**3.** ↔ f	**4.** ↔ h	**5.** ↔ g
6. ↔ a	**7.** ↔ c	**8.** ↔ d		

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21

Matrix-Matching-Type Questions (Mixed)

Matrix A

1. Expansion of gas to fill a cylinder	(a) The work done is zero
2. $E^\circ_{Fe^{2+}\mid Fe} = -0.44$ V and $E^\circ(O_2 + 4H^+ + 4e = 2H_2O) = +1.23$ V	(b) A spontaneous process
3. Uniform mixing of Br_2 vapour and N_2 gas	(c) $\Delta S = -R\Sigma(x_i \ln x_i)$
4. $N_2O_4(g) \rightleftharpoons 2NO_2(g)$	(d) From colourless to brown

Matrix B

1. Minimum half-life period	(a) Polonium-212
2. $\log \lambda = A \log E + B$ is the mathematical form of Geiger–Nuttal rule	(b) Neutron decay
3. Beta negative decay	(c) $4n$, $4n + 2$ and $4n + 3$ series
4. Beta positive decay or electron capture	(d) $\Delta m = m_{\text{parent}} - m_{\text{daughter}} > 0$

Matrix C

1. Transition between two atomic energy levels	(a) X-rays
2. Electron emission from a material	(b) Photoelectric effect

3. Moseley's law	(c) Hydrogen spectrum
4. Change of photon energy into kinetic energy of electrons	(d) β-decay

Matrix D

1. Steam engine	(a) Energy conversion
2. Galvanic cell	(b) Redox reactions
3. Lead storage cell	(c) A primary cell
4. Leclanché cell	(d) A secondary cell

Matrix E

1. $(CH_3)_3CBr + H_2O \rightarrow$	(a) A pseudo-unimolecular reaction
2. $HCOOH(aq) + Br_2(aq) \rightarrow$	(b) A first-order reaction
3. $H_2(g) + I_2(g) \rightarrow 2HI(g)$	(c) A fractional-order reaction
4. $CH_3CHO(g) \rightarrow CH_4(g) + CO(g)$	(d) A zero-order reaction

Matrix F

1. Zinc blende has a hexagonal close-packed structure	(a) The crystal has a 6 : 6 coordination
2. Wurzite has a cubic close-packed structure	(b) Space occupancy = 74%
3. The crystal having an fcc structure and maintaining equal numbers of cation and anion vacancies	(c) The crystal has alternate tetrahedral void
4. Anisotropic properties	(d) The crystal has the coordination number 4 and possesses Frenkel defects

Matrix G

1. Lyophilic sol	(a) Isoelectric point
2. Tyndall cone	(b) Self-stabilized sol

3. Process of converting a suspension into a colloidal solution by the addition of electrolyte	(c) Coagulation
4. Precipitation of a colloidal solution by the addition of electrolyte	(d) Peptization

Matrix H

1. Depression of freezing point	(a) The vapour pressure of a solution is less than that of the pure solvent
2. Elevation of boiling point	(b) Only solvent molecules solidify at the freezing point
3. Elevation of freezing point	(c) Addition of $K_4[Fe(CN)_6]$
4. The van't Hoff factor may be less than or greater than one	(d) During complexation

Matrix I

1. Negative deviation from Raoult's law	(a) Benzene–methanol system
2. Positive deviation from Raoult's law	(b) Acetone–ethanol system
3. Minimum boiling azeotrope	(c) Water–hydrochloric acid system
4. Maximum boiling azeotrope	(d) $\Delta H_{\text{mix}} > 0$ and $\Delta V_{\text{mix}} > 0$

Matrix J

1. Change in Gibbs free energy	(a) An extensive property
2. Enthalpy change	(b) Efficiency of energy conversion
3. Entropy change	(c) $dw_{\text{add, max}}$
4. dG	(d) $\Delta H - nF \left.\frac{\partial E}{\partial T}\right]_p$

Matrix K

1. Equivalent conductivity of a weak electrolyte at infinite dilution	(a) Kohlrausch's law
2. Molar conductivity at infinite dilution (Λ_m°)	(b) $\nu_+ \lambda_+ + \nu_- \lambda_-$
3. Limiting molar conductivity	(c) $\Lambda_m + Kc^{1/2}$
4. Parameter which changes with dilution	(d) Solubility product

Answers

Matrix A

	a	b	c	d
1	●	●	○	○
2	○	●	○	○
3	●	●	●	○
4	○	○	○	●

Matrix B

	a	b	c	d
1	●	○	●	○
2	○	○	●	○
3	○	○	●	●
4	○	○	○	●

Matrix C

	a	b	c	d
1	●	○	●	○
2	●	●	○	●
3	●	○	○	○
4	○	●	○	○

Matrix D

	a	b	c	d
1	●	○	○	○
2	●	●	○	○
3	●	●	○	●
4	●	○	●	○

Matrix E

	a	b	c	d
1	●	●	○	○
2	○	●	○	○
3	○	○	○	●
4	○	○	●	○

Matrix F

	a	b	c	d
1	○	●	●	●
2	○	●	○	●
3	●	●	○	○
4	●	●	●	●

Matrix G

	a	b	c	d
1	●	●	○	○
2	○	●	●	○
3	○	○	○	●
4	○	●	●	○

Matrix H

	a	b	c	d
1	●	●	●	○
2	●	○	●	○
3	○	○	○	●
4	○	○	●	●

Matrix I

	a	b	c	d
1	○	●	●	○
2	●	○	○	●
3	●	○	○	●
4	○	●	●	○

Matrix J

	a	b	c	d
1	●	○	●	●
2	●	●	○	○
3	●	○	○	○
4	○	○	●	○

Matrix K

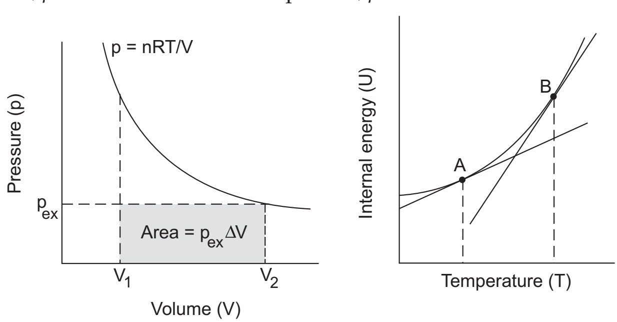
	a	b	c	d
1	●	○	●	●
2	●	●	●	●
3	○	●	○	○
4	○	●	●	○

❑

22

Comprehension-Type Questions

- In thermodynamics, the work done by a gas when it expands against a constant external pressure, p_{ex}, is equal to the area $p_{ex}\Delta V$. The work done by a perfect gas when it expands reversibly and isothermally is equal to $-nRT\int_{V_1}^{V_2}\frac{dV}{V}$. But due to irreversible expansion at the same final pressure, the work done is equal to $p_{ex}\Delta V$. The work done is greater in reversible process than in irreversible process. The internal energy thus produced in the system is plotted against temperature at constant volume. The slope will be the heat capacity. A similar graph can be plotted between enthalpy (H) and temperature (T). The internal energy during adiabatic process is $C_V\Delta T$. In isothermal process, $p \propto 1/V$, and in adiabatic process, $p \propto 1/V^{\gamma}$.



1. The energy transferred as heat to a system at constant volume is equal to

(a) ΔU (b) IVt (c) ΔH (d) $đq + đw$

2. From the graph,

(a) the heat capacity is lesser at B than at A

(b) $C_p < C_V$

(c) the heat capacity is greater at B than at A

(d) the heat capacity at B is equal to that at A

3. Indicate the correct statement for ideal gases.

(a) $C_{p,\,\mathrm{m}} - C_{V,\,\mathrm{m}} = R$

(b) The slope of the graph of enthalpy versus temperature is steeper than that of the graph of internal energy versus temperature

(c) The slope of the graph of internal energy versus temperature is steeper than that of the graph of enthalpy versus temperature

(d) $C_{p,\,\mathrm{m}}/C_{V,\,\mathrm{m}} = \gamma = \frac{4}{3}$ for a gas with nonlinear polyatomic molecules

4. Which of the following is the correct expression for adiabatic process?

(a) $PV^{\gamma} = \text{constant}$

(b) $VT^{C_{V,\,\mathrm{m}}/R} = \text{constant}$

(c) $\Delta U = W_{\mathrm{ad}}$

(d) All of these

5. The molar heat capacity of water in equilibrium with ice at constant pressure is

(a) zero

(b) infinity (∞)

(c) 40.45 kJ $\mathrm{K^{-1}\,mol^{-1}}$

(d) 75.48 J $\mathrm{K^{-1}\,mol^{-1}}$

6. In a given process on an ideal gas, $dw = 0$ and $dq < 0$. Then, for the gas, the

(a) temperature will decrease

(b) volume will increase

(c) pressure will remain constant

(d) temperatue will increase

- The colligative property of a solution is a property that depends only on the number of solute particles present, not on their identity. An ideal solution is a solution in which all components obey Raoult's law (i.e., $p_{\mathrm{A}} = x_{\mathrm{A}} p_{\mathrm{A}}^{\circ}$) throughout the composition range. The vapour pressure of a binary volatile mixture is $p = p_{\mathrm{B}}^{\circ} + (p_{\mathrm{A}}^{\circ} - p_{\mathrm{B}}^{\circ})x_{\mathrm{A}}$. The composition of the vapour is given by $y_{\mathrm{A}} = x_{\mathrm{A}} p_{\mathrm{A}}^{*}/\{p_{\mathrm{B}}^{*} + (p_{\mathrm{A}}^{*} - p_{\mathrm{B}}^{*})\}x_{\mathrm{A}}$ and $y_{\mathrm{B}} = 1 - y_{\mathrm{A}}$. The total vapour pressure of a mixture is $p = p_{\mathrm{A}}^{*} p_{\mathrm{B}}^{*}/p_{\mathrm{A}}^{*} + (p_{\mathrm{B}}^{*} - p_{\mathrm{A}}^{*})y_{\mathrm{A}}$. Azeotrope is a mixture that boils without change in composition. In colligative properties, the elevation of boiling point is given by $\Delta T = K_{\mathrm{b}} m$ and the depression of freezing point by $\Delta T = K_{\mathrm{f}}\, m$. During dissociation of ionic electrolytes, the van't Hoff factor equals

$$i = 1 + (n - 1)\alpha = \frac{M_{\mathrm{th}}}{M_{\mathrm{obs}}}\cdot$$

During association of electrolytes,

$$i = 1 - \beta + \frac{\beta}{n} = \frac{M_{\mathrm{th}}}{M_{\mathrm{obs}}}\cdot$$

Here α and β are the degrees of dissociation and association, respectively, of electrolytes.

7. The vapour-phase compositions in two binary liquid mixtures follow

(a) Boyle's law

(b) Dalton's law

(c) Raoult's law

(d) Henry's law

8. The mole fraction of a solute is 0.4. The relative lowering of vapour pressure is

(a) 60% (b) 80% (c) 40% (d) 20%

9. The van't Hoff factor is 3 for

(a) Na_2SO_4

(b) $Al_2(SO_4)_3$

(c) $CaCl_2$ with 80% disociation

(d) $K_4[Fe(CN)_6]$ with 50% dissociation

10. The most accurate method for the measurement of molar mass is

(a) osmotic pressure (b) ebullioscopy

(c) cryoscopy (d) Raoult's law

11. The freezing point of a solution containing 0.2 g of acetic acid in 20.0 g benzene is lowered by 0.45°C. The degree of association of acetic acid is (given that K_f for benzene is 5.12 K kg mol^{-1})

(a) 0.985 (b) 0.945 (c) 0.845 (d) 0.795

12. In a 0.2-molal aqueous solution of a weak acid HX, the degree of ionization is 0.3. If K_f for water is 1.86 K kg mol^{-1}, the freezing point of the solution is nearly equal to

(a) –0.480°C (b) –3.56°C (c) –0.260°C (d) 0.48°C

- According to the nature of the forces which are holding the gaseous molecular species over the surface of the solid, adsorption can be classified as physisorption and chemisorption. In *physisorption,* the molecules are held by van der Waals forces. This process has $\Delta H^\circ_{ads} = -20$ kJ mol^{-1}; occurs at low temperatures; is reversible, having almost zero activation energy; shows multilayer phenomena; is a function of only the adsorbate; adsorption increases with pressure. On the other hand, in *chemisorption,* the molecules are held by strong chemical forces. This process has $\Delta H^\circ_{ads} = -200$ kJ mol^{-1}; occurs at high temperatures, having activation energy; shows unilayer phenomena; is a function of both the adsorbate and adsorbent; adsorption decreases with pressure.

  Easily liquefiable gases and consequently larger cohesive force are more easily adsorbed. Adsorption is accompanied by decrease in entropy. The amount of gas adsorbed (x) on the mass of the adsorbent (m) is the function of both pressure and temperature. The variation of amount of gas adsorbed per unit mass with pressure is expressed by empirical equation given by Freundlich as $\frac{x}{m} = kp^{1/n}$ where k, n are constants depending upon the nature of adsorbent. This equation is also applicable in solution. At high pressure of gases, deviation occurs. In order to rectify the deviation, Irving Langmuir modified the above equation as

$$\frac{x}{m} = \theta = \frac{bp}{1 + bp},$$

  where $b = \frac{K_a}{K_d}$, K_a = rate constant for adsorption, K_d = rate constant for desorption.

13. Physical adsorption is
(a) a monolayer phenomenon (b) a multilayer phenomenon
(c) both (a) and (b) (d) none of these

14. In the Freundlich adsorption isotherm, when $\frac{1}{n} = 0$, $\frac{x}{m}$ is
(a) $\frac{1}{k}$ (b) zero (c) k (d) infinity

15. In the adsorption isotherm,
(a) $\frac{x}{m} = f(p)$ (b) $\frac{x}{m} = f(T)$
(c) $\frac{x}{m} = \text{constant}$ (d) $\frac{x}{m} = f(V)$

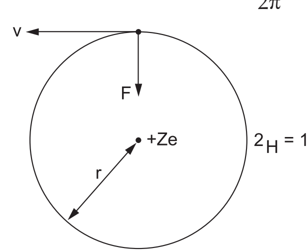
16. Which of the following is true during adsorption?
(a) $\Delta H°$ is negative. (b) $\Delta G°$ is negative.
(c) $\Delta S°$ is negative. (d) All of these

17. At equilibrium in adsorption,
(a) $\Delta S° = \frac{\Delta H°}{T}$ (b) $\Delta G° = 0$
(c) $\Delta G° < 0$ (d) $\Delta G° = \infty$

18. When $k = 1$, the surface coverage is
(a) 25% (b) 75% (c) 50% (d) 100%

19. The surface coverage, θ, is related to the pressure and the equilibrium constant by the Langmuir isotherm,
(a) $\theta = \frac{bp}{1 + bp}$ (b) $\theta = bp$
(c) $\theta = \frac{1 + bp}{bp}$ (d) $\theta = \frac{b}{p}$

- The Bohr model is represented by the figure shown, where v = tangential speed.The attractive coulomb force provides the centripetal acceleration v^2/r. The angular momentum, $\vec{L} = \vec{r} \times \vec{p} = mvr$. Thus Bohr's postulate is $mvr = \frac{nh}{2\pi}$.
When the electron and the nucleus are separated by an infinite distance corresponding to $n = \infty$, we have $E = 0$. We might begin with the electron and electron is separated by an infinite distance and then bring the electron closer to the nucleus until it is in the orbit in a particular state n. Since this state has less energy than $E = 0$, with which we began. We have 'gained' an amount of energy equal to E_n. Conversely,



if we have an electron in a state n, we can 'take the atom apart' by supplying an energy E_n. This energy is known as the *binding energy* of the state n. If we supply more energy than $E_n = -13.6$ eV, the excess energy will appear as the kinetic energy of free electrons.

The excitation energy of an excited state n is just the energy above the ground state, $E_n - E_1$. Thus for the first excited state, $n = 2$, has excitation energy $= -3.4 - (-13.6) = 10.2$ eV. Similarly, the second excited state is 12.1 eV. The photon appears with energy $h\nu = E_{n_1} - E_{n_2}$ or $hc/\lambda = hc\bar{\nu} = E_{n_1} - E_{n_2}$. The Balmer formula $\lambda = 364.5$ nm $(n_1^2/n_1^2 - 4)$. There are five spectral series only, Lyman series appears in the absorption spectra, all series are present in the emission spectrum.

20. The Bohr-orbit radius for the hydrogen atom ($n = 1$) is approximately 0.53 Å. The radius for the first excited state ($n = 2$) orbit is

(a) 0.27 Å (b) 1.27 Å (c) 2.12 Å (d) 3.12 Å

21. The wavelength of the first line of the Balmer series is approximately

(a) 212 nm (b) 654 nm (c) 120 nm (d) 446 nm

22. If the radius of the nth orbit is directly proportional to E_n^x, the value of x will be

(a) +2 (b) +1 (c) –2 (d) –1

23. The angular momentum in lowest orbit is

(a) 2 (b) 1 (c) 0 (d) ∞

24. The ratio of v_n/K_n (v_n being the velocity of an electron in the nth shell and K_n being the kinetic energy of the nth shell) is

(a) +2 (b) –2 (c) –1 (d) +1

25. If $\frac{1}{r^n} \propto Z^y$ (Z = atomic number) the value of y will be

(a) 2 (b) 3 (c) 4 (d) 1

- A buffer solution is one which is resistant to change in pH by the addition of small amount of acid or alkali. The acidic buffer consists of (a) the weak acid CH_3COOH and a salt of its conjugate base CH_3COONa (b) $CH_3COOH + NaOH$ (2 : 1 molar ratio) (c) $CH_3CONa + HCl$ (2 : 1 molar ratio. Similarly, the basic buffer consists of (a) week base, NH_3 and a salt of its conjugate acid (NH_4Cl) (b) $NH_3 + HCl$ (2 : 1 molar ratio) (c) $NH_4Cl + NaOH$ (2 : 1 molar ratio). The pH of a buffer solution is given by the Henderson equations, $\text{pH} = \text{p}K_a + \log \frac{[\text{salt}]}{[\text{acid}]}$ (for acidic buffer) and $\text{pOH} = \text{p}K_b + \log \frac{[\text{salt}]}{[\text{base}]}$ (for basic buffer). Addition of a small amount of acid or base causes a little change in pH. Range of pH is $\text{pH} = \text{p}K_a \pm 1$ or $\text{pOH} = \text{p}K_b \pm 1$. The unit change in pH by the addition of acid or alkali is called the *buffer capacity*.

26. The buffer capacity is defined as

(a) $d\text{pH}/dn_{\text{acid or base}}$ (b) $d\text{pH}/\text{p}K_a$ or $\text{p}K_b$

(c) $dn_{\text{acid or base}}/d\text{pH}$ (d) $d\text{pH}/\text{p}K_a + \text{p}K_b$

27. A buffer solution is one which has
(a) reserve acidity
(b) reserve alkalinity
(c) a pH equal to 7
(d) reserve acidity and reserve alkalinity

28. 0.1 mol of CH_3NH_2 ($K_b = 5 \times 10^{-4}$ mol L^{-1}) is mixed with 0.08 mol of HCl and diluted to 1 L. What will be the H^+ ion concentration of the resulting solution?
(a) 8×10^{-2} mol L^{-1} (b) 8×10^{-11} mol L^{-1}
(c) 1.6×10^{-11} mol L^{-1} (d) 8×10^{-5} mol L^{-1}

29. The pH of a buffer solution depends upon
(a) concentration of salt
(b) concentration of either acid or base
(c) the ratio of salt and acid or salt and base
(d) pK_a or pK_b

30. Which pair will show the common-ion effect?
(a) $MgCl_2$ and $Mg(NO_3)_2$ (b) KCl and HCl
(c) $C_6H_5NH_2$ and $C_6H_5NH_3Cl$ (d) $AuCl_3$ and $Au(OH)_3$

31. A buffer solution can be prepared from a mixture of
(a) sodium acetate and acetic acid in water
(b) sodium acetate and hydrochloric acid in water
(c) ammonia and ammonium chloride in water
(d) all of these

- The feasibility of a reaction is determined by ΔG. Consider a gaseous reaction of the type

$$n_1\mathrm{A} + n_2\mathrm{B} \rightleftharpoons n_3\mathrm{C} + n_4\mathrm{D}.$$

ΔG is related to the reaction quotient as

$$\Delta G = \Delta G° + RT \ln Q$$

For the above reaction,

$$\Delta G = \Delta G° + RT \ln \frac{C_\mathrm{C}^{n_3} \cdot C_\mathrm{D}^{n_4}}{C_\mathrm{A}^{n_1} \cdot C_\mathrm{B}^{n_2}}$$

At equilibrium, $\Delta G = 0$.

$\therefore \quad \Delta G° = -RT \ln K_p \quad$ or $\quad \Delta G = -RT \ln K_p + RT \ln Q = RT \ln \frac{Q}{K_p}\cdot$

$\Delta G°$ is related to $\Delta H°$ as

$$\Delta G° = \Delta H° - T\Delta S° \qquad \text{(at standard conditions).}$$

The relation between K_p and K_n are

$$K_p = \frac{n_C^{n_3} \cdot n_D^{n_4}}{n_A^{n_1} \cdot n_B^{n_2}} \left(\frac{P}{\Sigma n}\right)^{\Delta n},$$

where Σn = total number of moles after the addition of inert gases.
For the reaction

$$n_1\text{A} + n_2\text{B} \rightleftharpoons n_3\text{C} + n_4\text{D},$$

we have

$$K_p = \frac{p_C^{n_3} \cdot p_D^{n_4}}{p_A^{n_1} \cdot p_B^{n_2}} \quad \text{and} \quad K_c = \frac{c_C^{n_3} \cdot c_D^{n_4}}{c_A^{n_1} \cdot c_B^{n_2}}.$$

K_p and K_c are related by

$$K_p = K_c \left(\frac{c^\circ RT}{p^\circ}\right)^{\Delta n}.$$

32. The unit of K_c
(a) depends on Δn
(b) depends upon the speed of reaction
(c) depends on the concentration
(d) is always mol L^{-1}

33. For the feasibility of reaction,
(a) $Q = K_p$
(b) $Q < K_p$
(c) $Q > K_p$
(d) all of these are true

34. Addition of inert gases on equilibrium $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ at constant volume
(a) will shift the equilibrium to the right
(b) will shift the equilibrium to the left
(c) the equilibrium will remain unchanged
(d) will explode the reaction

35. ΔG_f° of $N_2O_4(g)$ and $NO_2(g)$ are respectively –100 kJ mol^{-1} and –50 kJ mol^{-1}. An equilibrium mixture of $N_2O_4(g)$ and $NO_2(g)$ is enclosed in a vessel at a pressure of 20 atm and a temperature of 25°C. In which direction will the reaction $2NO_2(g) \rightleftharpoons N_2O_4(g)$ proceed?
(a) Forward direction
(b) Reverse direction
(c) The reaction will remain in equilibrium.
(d) Data are insufficient.

36. The spontaneous reaction is not easily possible if
(a) both ΔH and ΔS are negative
(b) both ΔH and ΔS are positive
(c) ΔH is negative and ΔS is positive
(d) ΔH is positive and ΔS is negative

- The rate of reaction is the change of concentration of reactant or product with time. The rate law for the reaction $aA + bB \rightarrow cC + dD$ the rate law is rate $= k[A]^a[B]^b$. The rate of reaction is calculated by knowing k, a and b. The rate laws are determined experimentally. The order of reaction is always defined in terms of reactants.

  During the collisions among two A and two B molecules, doubling the number of either type of molecule increases the number of collisions to eight. The species temporarily formed by the reactant molecules as a result of the collision before they form the product is called the *activated complex*. The temperature-dependent rate constant is given by the Arrhenius equation.

  In many cases, the sum of a series of simple reactions are called elementary steps or elementary reactions because they represent the progress of the overall reaction at the molecular level. The sequence of elementary steps that leads to product formation is called the *reaction mechanism*. The number of molecules reacting in an elementary step determines the molecularity of a reaction.

37. For a zero-order reaction the plot of the rate of reaction versus [A] gives
  (a) a zigzag line
  (b) a straight line
  (c) a straight line with negative slope
  (d) none of these

38. On which of the following quantities does the rate constant of a reaction depend?
  (a) Concentrations of reactants (b) Nature of reactions
  (c) Temperature (d) All the above

39. Instantaneous rate of reaction is measured from the
  (a) graph of time versus concentration
  (b) molecularity of reaction
  (c) integration method
  (d) reaction mechanism of a reaction

40. The order of reaction is always defined in terms of
  (a) product concentration
  (b) rate constant of a reaction
  (c) reactant concentration
  (d) ratio of the product concentration to the reactant concentration

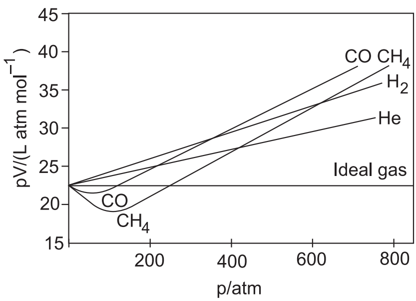
41. During the collision between A and B molecules, doubling the A and B molecules increases the number of collisions to
  (a) 4 (b) 8 (c) 32 (d) 16

42. In terms of collision theory the rate of reaction is
  (a) proportional to the number of molecular collision per second
  (b) frequency of the molecular collisions
  (c) depend on concentration of reactants
  (d) all of these

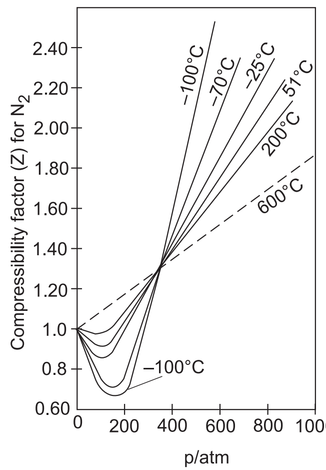
43. The number of molecules reacting in an elementary step of a reaction may be

(a) 1 (b) $\frac{1}{2}$ (c) $\frac{3}{2}$ (d) 5

- The compressibility factor, Z, is defined by the relation $Z = \frac{pV}{nRT}\cdot$ For ideal gases, $Z = 1$ at all temperatures and pressures. The deviation from unity is an index of deviation from ideal behaviour.



The pV versus p plot for some gases at 0°C



Z may be calculated from the above equation. Plot of $pV \rightarrow p$ and $Z \rightarrow p$ is shown. Actually $p = 0$ to $p = 100$ atm Z changes only from 1.00 to 1.02. Beyond 100 atm Z increases rapidly with pressure and attains value above $Z = 1$. This temperatue at which a real gas obeys ideal gas law over an appreciable range of pressure is called the Boyle temperature or Boyle point (T_B). Above T_B the gas shows only positive deviations from ideality, so $Z > 1$.

After making correction on pressure and volume on ideal gas equation, van der Waals derived the following eqn of state for a real gas for n moles $(p + n^2a/v^2)(v - nb) = nRT$, where a and b are the van der Waals constants. This equation is valid for wider range of pressure.

44. The compressibility factor (Z) for a real gas at a very high temperature and a very low pressure is

(a) $Z \rightarrow \infty$ (b) $Z > 1$ (c) $Z < 1$ (d) $Z = 1$

45. The compressibility factor (Z) for a real gas at a moderately low pressure is given by

(a) $\frac{pV}{nRT}$ (b) $1 + \left(\frac{bp}{nRT}\right)$

(c) $1-\left(\frac{bp}{nRT}\right)$ (d) $1+\left(\frac{pV}{nRT}\right)$

46. The Boyle temperature (T_B) is given by

(a) $\frac{a}{bR}$ (b) $\frac{a}{R}$ (c) $\frac{ab}{R}$ (d) $\frac{bR}{a}$

47. Identify the conditions of pressure and temperature at which a real gas shows maximum deviation from ideality.

(a) 12 atm, 273 K (b) 7 atm, 273 K
(c) 12 atm, 373 K (d) 7 atm, 373 K

48. Which of the following gases has the least intermolecular force of attraction? (Use the first figure.)

(a) He (b) CO (c) CH_4 (d) CO_2

49. At which of the following temperatures the maximum dip N_2 shows? (Use the second figure.)

(a) –25°C (b) –70°C (c) 200°C (d) –100°C

50. Which of the following gases are easily condensed and has the maximum value of *a*?

(a) NH_3 (b) H_2O (c) SO_2 (d) CO_2

- The atmosphere contains both $^{12}CO_2$ and $^{14}CO_2$. These $^{12}CO_2$ and $^{14}CO_2$ are consumed by plants and animals. The concentration of ^{14}C in living organism remains almost constant for longer time. When plants or animal dies, they are no longer in a position to take up CO_2 from the atmosphere. ^{14}C is assimilated by animal or plant during its life time, after that the species begins to decay by emitting β-particles, which have a half-life of 5760 years. The decay rate is 15.3 counts per minute per gram of carbon. Now measuring the decay rate of a sample of dead matter (wood, fossils etc.) at any period from the date, it is possible to calculate the life of a living body which had died. The half-life is calculated by using the equation $N = N_0 e^{-\lambda t}$ or $t = \frac{2.303}{\lambda} \log \frac{N_0}{N}$.

51. ^{14}C is produced in the atmosphere by the nuclear reaction of

(a) $^{14}C(n, p)$ (b) $^{14}N(n, p)$
(c) $^{15}N(n, p)$ (d) $^{12}C(n, p)$

52. The radioactivity due to ^{14}C isotope ($t_{1/2} = 5760$ years) of a sample of wood from an ancient tomb was found to be nearly half that of fresh wood. The tomb is, therefore, about

(a) 5760 years old (b) 2880 years old
(c) 11520 years old (d) 4320 years old

53. A piece of wood recovered in an excavation has 25.6% as much as ^{14}C as ordinary wood has when did this piece get burried? ($t_{1/2}$ of ^{14}C is given 5760 years)

(a) 22649.6 years (b) 5662.4 years
(c) 2831.2 years (d) 11324.8 years

54. The scientist who was awarded the Nobel prize for chemistry in 1960 for the discovery of carbon-14 dating is

(a) Willard Libby (b) Otto Hahn
(c) Hideki Yukawa (d) Hans Bethe

55. The age of fossils is determined by

(a) ^{14}C (b) ^{40}K (c) ^{238}U (d) all of these

- In the Daniell cell, the copper electrode is the anode. The electrons leave the cell from the zinc and enter into the copper electrode. To complete the circuit a salt bridge (an inverted U-tube) is used. Salt bridge consists of a concentrated solution of agar-agar + $KCl/KNO_3/NH_4NO_3$. The mobility of cations and anions are the same. The maximum electrical work is given by $W_{e,\,max} = \Delta G$. This ΔG is related to emf as $\Delta G = -nFE$. The extent of reaction is measured by ΔG. The emf of a cell is determined by the Nernst equation, $E = E° - \frac{0.0592}{n} \log Q$. The Nernst equation is also used to calculate the emf of concentration cell. $M \mid M^+(aq, L) \parallel M^+(aq, R) \mid M$. When a given cell is at equilibrium, $Q = K_{eq.}$ To calculate the standard electrode potential of a cell like Ag/Ag^+, Cu/Cu^{2+}, one has to complete it with SHE e.g. $Pt/H_2(g)/H^+(aq)$ its $E° = 0$ (by convention). From the emf study, we can calculate $E°$, pH, valency, K_{eq}, K_s, thermodynamic parameters, etc.

56. The electrical energy of a Daniell cell produces due to

(a) movement of cations and anions
(b) increase in ΔS
(c) decrease in ΔH
(d) decrease in ΔG

57. The simplest reference electrode is the

(a) SHE (b) calomel electrode
(c) O_2 electrode (d) quinhydrone electrode

58. The least strongly reducing metal is

(a) copper (b) silver
(c) platinum (d) gold

59. The most strongly reducing metal is

(a) sodium (b) zinc (c) calcium (d) iron

60. The standard potential of a Daniell cell is +1.10 V. The equilibrium constant for cell reaction is

(a) 1.5×10^{12} (b) 1.5×10^{37}

(c) 1.5×10^{22} (d) 1.5×10^{30}

61. When a calomel electrode is coupled with hydrogen electrode, the pH of the cell is given by

(a) $\text{pH} = \dfrac{E + E_{\text{cal}}}{0.0592}$ (b) $\text{pH} = \dfrac{E - E_{\text{cal}}}{0.0592}$

(c) $\text{pH} = \dfrac{E_{\text{cal}}}{0.0592}$ (d) $\text{pH} = \dfrac{2E + E_{\text{cal}}}{0.0592}$

62. The temperature coefficient is given by

(a) $\dfrac{dE^\circ}{dT} = \dfrac{\Delta S^\circ}{n}$ (b) $\dfrac{dE^\circ}{dT} = \dfrac{\Delta S^\circ}{F}$

(c) $\dfrac{dE^\circ}{dT} = \dfrac{\Delta S^\circ}{nF}$ (d) $\dfrac{dE^\circ}{dT} = \dfrac{\Delta G^\circ}{nF}$

63. The solubility, S, of a sparingly soluble 1 : 1 salt is related to the solubility product, K_s, by

(a) $S = K_s^2$ (b) $S^{1/2} = K_s$

(c) $S = K_s^{3/2}$ (d) $S = K_s^{1/2}$

Answers

1. b	**2.** c	**3.** a, b, d	**4.** d	**5.** b	**6.** a
7. b	**8.** c	**9.** d	**10.** c	**11.** b	**12.** a
13. b	**14.** c	**15.** a	**16.** d	**17.** a	**18.** c
19. a	**20.** c	**21.** b	**22.** d	**23.** c	**24.** b
25. d	**26.** a	**27.** d	**28.** b	**29.** c, d	**30.** c
31. d	**32.** a	**33.** b	**34.** c	**35.** a	**36.** d
37. b	**38.** a	**39.** a	**40.** c	**41.** d	**42.** d
43. a	**44.** d	**45.** b	**46.** a	**47.** c	**48.** a
49. d	**50.** b	**51.** b	**52.** a	**53.** d	**54.** a
55. a	**56.** d	**57.** a	**58.** d	**59.** c	**60.** b
61. a	**62.** c	**63.** d			

❑

23

Integer-Answer-Type Questions

• Set I •

1. Calculate the coordination number of carbon in diamond.

2. Calculate the change in the oxidation state of Mn when $KMnO_4$ reacts with concentrated HCl to produce the Mn^{2+} ion.

3. Calculate the value of the equilibrium constant, by using the relationship between K and $\Delta G°$. Given $E^0 = 0.028$ V.

4. Compute the time required to pass 36000 C through an electroplating bath using a current of 5 A.

5. 20.0 mL of 0.2 M NaOH is added to 50.0 mL of 0.2 M CH_3COOH to give 70.0 mL of the solution. Calculate the additional volume of the 0.2 M NaOH required to make the pH of the solution 4.74 (pK_a for CH_3COOH = 4.74.)

6. For a reaction $3A \rightarrow B + C$ with a constant rate at every concentration of A, find the order of the reaction with respect to A.

7. The difference between wavelengths for the first lines of the Balmer series and the Lyman series is 59.3 nm for a hydrogen-like ion. Calculate the value of Z. (Given $R_H = 109{,}678$ cm^{-1}.)

8. 25.4 g of iodine and 14.2 g of chlorine are made to react completely to yield a mixture of ICl and ICl_3. Calculate the ratio of the moles of ICl and ICl_3 formed.

❑

• Set II •

1. The dichromate ion reacts with an NaOH solution to produce the chromate ion. Calculate the change in the oxidation number of chromium during this transformation.

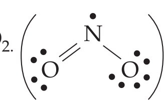
2. Indicate the overall order of the following reaction.

$$3I^- + S_2O_8^{2-} \rightarrow I_3^- + 2SO_4^{2-}$$

3. 10.0 A of current flowed for 1.0 hour through water containing a little sulphuric acid. How many litres of gas were formed at both electrodes at 27°C and 740 mm pressure?

4. Calculate the ratio of the value of any colligative property for a $K_4[Fe(CN)_6]$ solution (assuming complete dissociation) to that of the corresponding property for a sucrose solution.

5. How much calcium (in g) is present in $Ca(NO_3)_2$ that contains 1.4 g of nitrogen?

6. Calculate the resonance energy of NO_2.  Bond energies of $N-O$, $N=O$, $N\equiv N$ and $O=O$ are 222, 607, 946 and 498 kJ mol^{-1} respectively. Given, ΔH of NO_2 is 134 kJ mol^{-1}.

7. 1.5 g of an organic acid was dissolved in water and the volume made up to 300 mL. 10.0 mL of this acid required 12.3 mL of $^N/_{10}$ NaOH for complete neutralization. If the molecular weight of the acid be 122.0, find the basicity of the acid.

8. Calculate the pH of a 0.1 M CH_3COONH_4 solution. Given, pK_a of CH_3COOH is 4.74 and pK_a of NH_3 is 4.74.

❑

• Set III •

1. The chromate ion reacts with an HCl solution to produce the dichromate ion. Calculate the change in the oxidation number of chromium during this transformation.

2. How many litres of water should be added to 10.0 g of acetic acid to give a hydrogen ion concentration equal to 1.0×10^{-3} M. ($Ka = 1.8 \times 10^{-5}$.)

3. Calculate the order of reaction for the gas-phase reaction $2NO_2 + O_3 \rightarrow N_2O_5 + O_2$, which has the rate constant $K = 2.0 \times 10^4$ dm^3 mol^{-1} s^{-1} at 300 K.

4. The lattice of crystelline $CoCl_2$ is body-centred tetragonal with 16 formula units per unit cell. How many molecules does the basis consist of?

5. An aqueous solution containing an ionic salt with molality equal to 0.1892 freezes at –0.704°C. Calculate the van't Hoff factor of the ionic salt. (K_f for water = 1.86 K/m.)

6. Calculate the value of the reaction quotient Q for the cell $Zn(s) \,|\, Zn^{2+}(0.01\text{ M}) \,||\, Ag^{+}(0.05\text{ M}) \,|\, Ag(s)$.

7. 10.0 g of $CaCO_3$ is placed in a 10.0-L vessel at 1100 K. Calculate the approximate amount of $CaCO_3$ unreacted at this temperature, given that K_p for the reaction $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$ is 0.060 at 1100 K.

8. A gas is kept at 1 atm. It is compressed to ¼th of its initial volume. Calculate the pressure applied .

❑

• Set IV •

1. Metallic iron can exist in the β form. (bcc, cell dimension = 2.90 Å) and the gamma (γ) form (fcc, cell dimension = 3.68 Å). The β form can be converted into the γ form by applying high pressures. Calculate the ratio of the density of the β form to that of the γ form.

2. The emf of the cell Ni(s) | Ni^{2+} (0.10 M) || HCl (a = ?) | H_2 (g, 1 atm) | Pt(s) at 25°C is 0.1615 V. Calculate the pH of HCl solution, given $E^0_{Ni^{2+}/Ni} = -0.25$ V.

3. The rate of decomposition of a gas at a certain temperature is 5.14 and 7.25 in some units for 20% and 5% decomposition respectively. Calculate the order of the reaction.

4. 0.05 M HA is titrated against a 0.05 M NaOH solution. Find the pH at the equivalence point. The dissociation constant for the acid HA is 5.0×10^{-6}.

5. The formula weight of an acid is 123 g mol^{-1}. 100 mL of a solution of this acid containing 39.0 g of the acid per litre was completely neutralized by 95.0 mL of aqueous NaOH containing 40.0 g of NaOH per litre. Calculate the basicity of this acid.

6. A gaseous reaction $A + 2B \rightleftharpoons 2C + D$ takes place in a reaction vessel kept at 25°C. The initial concentration of B is 1.5 times that of A. After the equilibrium is established, the concentrations of A and D are equal. Calculate the equilibrium constant for the reaction at 25°C.

7. 10.0 mL of a mixture of nitrogen and oxygen was mixed with 20 mL of hydrogen and the mixture then exploded. The volume after explosion was found to be 21.0 mL. Calculate the volume of nitrogen gas.

8. Water rises to a height of 6 cm in a capillary tube of radius r. If the radius is made $\frac{2r}{3}$, calculate the capillary rise in cm.

❑

Answers

Set I

1. 8	**2.** 0	**3.** 3	**4.** 2	**5.** 5
6. 0	**7.** 3	**8.** 1		

Set II

1. 0	**2.** 2	**3.** 7	**4.** 5	**5.** 2
6. 8	**7.** 3	**8.** 7		

Set III

1. 0	**2.** 3	**3.** 2	**4.** 8	**5.** 2
6. 4	**7.** 9	**8.** 4		

Set IV

1. 1	**2.** 2	**3.** 2	**4.** 9	**5.** 3
6. 4	**7.** 7	**8.** 9		

❑

24

Numerical Problems

• *Objective Type* •

Choose the correct option. Only one option is correct.

1. Calculate the concentration of I_3^- ions in a standard solution of iodine in 0.5 M KI, making use of the following standard electrode potentials:

$$I_2 + 2e \rightleftharpoons 2I^-;\ E° = +0.5355 \text{ V and } I_3^- + 2e \rightleftharpoons 3I^-;\ E° = +0.5365 \text{ V}.$$

The molarity of I^- in the 0.5-M KI solution can be assumed to be 0.5 mol L^{-1}.

(a) 0.12 mol L^{-1} (b) 0.48 mol L^{-1}

(c) 0.88 mol L^{-1} (d) 0.24 mol L^{-1}

2. The boiling point of *n*-hexane at 760 Torr is 68.9°C. The critical temperature of *n*-hexane is

(a) 240 K (b) 513 K

(c) 531 K (d) 342 K

3. Consider an orthorhombic unit cell having dimensions $a = 487$ pm, $b = 646$ pm and $c = 415$ pm. Find the separation of the {222} planes of the crystal.

(a) 425 pm (b) 175 pm (c) 125 pm (d) 250 pm

4. Given that $r_{Na^+} = 0.55$ Å and $r_{Cl^-} = 1.81$ Å, calculate the dipole moment of NaCl. Assume that NaCl is 100% ionic in character.

(a) 8.74×10^{-29} C m (b) 3.78×10^{-29} C m

(c) 1.97×10^{-29} C m (d) 5.84×10^{-29} C m

5. Calculate the elevation of boiling point for an aqueous solution which contains 90 g of glucose and 45 g of urea in 1000 g of solvent water (given that the boiling point of water is 373 K and the entropy of vaporization per gram of water is 1.448 cal/°C at the boiling point).

(a) 0.85 K (b) 0.65 K (c) 1.65 K (d) 0.065 K

6. A monolayer of N_2 molecules, having an effective area of 0.20 nm^2, is adsorbed on the surface of 1.00 g of an Fe/Al_2O_3 catalyst at 77 K, which is the boiling point of liquid nitrogen. Upon warming, the nitrogen occupies 3.00 cm^3 at 0°C and 760 Torr. What is the surface area of the catalyst (given that $R = 0.0821$ L atm K^{-1} mol^{-1})?

(a) 16 m^2 (b) 18 m^2
(c) 14 m^2 (d) 20 m^2

7. The compressibility factor for one mole of a van der Waals gas at 273 K and 100 atm is found to be 0.5. Assuming the volume of the gas to be negligible, find the van der Waals coefficient a.

(a) 4.25 atm L^2 mol^{-1} (b) 2.25 atm L^2 mol^{-1}
(c) 5.25 atm L^2 mol^{-1} (d) 1.25 atm L^2 mol^{-1}

8. Calculate the Rydberg constant (R_∞) if He^+ ions are known to have a wavelength difference between the first lines of the Balmer and Lyman series equal to $\Delta\lambda = 133.7$ nm.

(a) 1.1×10^7 m^{-1} (b) 2.2×10^7 m^{-1}
(c) 1.1×10^9 m^{-1} (d) 1.1×10^5 m^{-1}

9. A solution contains oxalate and hydrogenoxalate ions but not any other material with either reducing or acidic properties. A sample of the solution decolorizes 48.0 mL of a 0.1-N $KMnO_4$ solution, and another sample of the same solution of equal volume neutralizes 18.0 mL of a 0.08-N KOH solution. What fraction of the oxalate ions present is protonated to hydrogenoxalate ions?

(a) 0.2 (b) 0.6 (c) 0.4 (d) 0.8

10. The time required for the 20% completion of a first-order reaction at 27°C is 1.5 times that required for its 30% completion at 37°C. If $A = 3 \times 10^9$ s^{-1}, calculate the time required for the 40% completion at 47°C. Also calculate the activation energy, E_a, for the reaction.

(a) 15 s; 88.8 kJ mol^{-1} (b) 29 s; 76.8 kJ mol^{-1}
(c) 29 s; 90.8 kJ mol^{-1} (d) 19 s; 67.6 kJ mol^{-1}

11. The emf of the cell

$$Hg(l)\,|\,Hg_2SO_4\,|\,H_2SO_4(1\text{ M})\,|\,PbSO_4(s)\,|\,Pb(s)$$

is –0.932 V. The cell reactions are as follows:

$$Hg_2SO_4 + 2e \rightleftharpoons 2Hg(l) + SO_4^{2-};\ E° = +0.62\text{ V}$$
$$PbSO_4 + 2e \rightleftharpoons Pb(s) + SO_4^{2-};\ E° = -0.36\text{ V}$$

Given that K_s for Hg_2SO_4 is 1.6×10^{-8} (mol L^{-1})^3, calculate the solubility product of $PbSO_4$ at 25°C.

(a) 7.0×10^{-12} (mol L^{-1})^2 (b) 3.0×10^{-11} (mol L^{-1})^2
(c) 6.6×10^{-7} (mol L^{-1})^2 (d) 1.8×10^{-9} (mol L^{-1})^2

12. LiBr, NaBr, KBr and RbBr have the same crystal structure shown by X-ray diffraction. The first three have the fcc structure. The structure of RbBr is

(a) face-centred cubic (b) body-centred cubic
(c) simple cubic (d) both (a) and (c)

13. The conductivity of pure water at 298 K is $5.55 \times 10^{-8}\ \Omega^{-1}\ \text{cm}^{-1}$. The molar conductivities of H^+ and OH^- ions at infinite dilution are $350\ \Omega^{-1}\ \text{cm}^2\ \text{mol}^{-1}$ and $200\ \Omega^{-1}\ \text{cm}^2\ \text{mol}^{-1}$ respectively. Calculate K_w of pure water at 298 K.

(a) $1.0 \times 10^{-12}\ (\text{mol L}^{-1})^2$ (b) $1.0 \times 10^{-14}\ (\text{mol L}^{-1})^2$
(c) $1.0 \times 10^{-16}\ (\text{mol L}^{-1})^2$ (d) $1.0 \times 10^{-18}\ (\text{mol L}^{-1})^2$

14. Metallic tin in the presence of HCl is oxidized by $K_2Cr_2O_7$ to stannic chloride. What volume of a decinormal dichromate solution would be reduced by 1 g of ${}^{119}_{50}\text{Sn}$?

(a) 525 mL (b) 168 mL
(c) 18 mL (d) 336 mL

15. The heat of neutralization of a weak acid in a normal solution by a strong alkali is 13 385 cal. Assuming that the acid is 14% dissociated in the normal solution, calculate the heat of dissociation of the acid.

(a) 236 cal (b) 366 cal
(c) 428 cal (d) 192 cal

16. The dissociation constants of acetic acid and benzoic acid are 1.80×10^{-5} mol L^{-1} and 7.32×10^{-5} mol L^{-1} respectively. Calculate the pH of a mixture of 20 g acetic acid and 10 g benzoic acid dissolved in one litre of water.

(a) 3.5 (b) 3.0 (c) 2.5 (d) 4.5

17. An electron in a hydrogen atom makes a transition $n_1 \to n_2$, where n_1 and n_2 are principal quantum numbers of the two states. Assume the Bohr model to be valid. The time period of the electron in the initial state is eight times that in the final state. What is the relation between n_1 and n_2?

(a) $n_1 = 4n_2$ (b) $n_1 = 2n_2$ (c) $2n_1 = n_2$ (d) $n_1 = n_2$

18. Green light has a wavelength of about 550 nm. To have this wavelength, an electron must be accelerated through a potential difference of

(a) 2 μV (b) 15 μV (c) 10 μV (d) 5 μV

19. Diamond crystallizes in a cubic unit cell in which there are carbon atoms at the positions (0 0 0), $\left(\frac{1}{2}\ \frac{1}{2}\ 0\right)$, $\left(\frac{1}{2}\ 0\ \frac{1}{2}\right)$, $\left(0\ \frac{1}{2}\ \frac{1}{2}\right)$, $\left(\frac{1}{4}\ \frac{1}{4}\ \frac{1}{4}\right)$, $\left(\frac{1}{4}\ \frac{3}{4}\ \frac{3}{4}\right)$, $\left(\frac{3}{4}\ \frac{1}{4}\ \frac{3}{4}\right)$ and $\left(\frac{3}{4}\ \frac{3}{4}\ \frac{1}{4}\right)$. What is the lattice parameter of this crystal if the density of diamond is 3.515 g cm^{-3}?

(a) 356.6 pm (b) 35.66 cm
(c) 556.8 Å (d) 0.568 nm

20. K_a for acetic acid is 1.8×10^{-5} mol L^{-1}. A decinormal solution of acetic acid is also 0.1-molar with respect to sodium acetate. Calculate the cell potential between a hydrogen electrode in this solution and a decinormal calomel electrode, assuming complete dissociation of the 0.1-M sodium acetate solution. $E°$ of the calomel electrode is +0.337 V.

(a) 0.544 V (b) 0.326 V
(c) 0.816 V (d) 0.618 V

21. For the reaction $2NO + H_2 \rightarrow 2NOH$, the following reaction mechanisms have been proposed.

Mechanism A.

Step I: $NO + H_2 \xrightleftharpoons{K} NOH_2$

Step II: $NOH_2 + NO \xrightarrow{k} 2NOH$

Mechanism B.

Step I: $2NO \xrightleftharpoons{K'} N_2O_2$

Step II: $N_2O_2 + H_2 \xrightarrow{k'} 2NOH$

On the basis of these two mechanisms we observe that the rate of the reaction is proportional to

(a) $[NO][H_2]$ (b) $[NO][H_2]^2$
(c) $[NO]^2[H_2]^2$ (d) $[NO]^2[H_2]$

22. If one mole of a monatomic gas $\left(\gamma = \frac{5}{3}\right)$ is mixed with one mole of a diatomic gas $\left(\gamma = \frac{7}{5}\right)$, calculate the value of γ for the mixture.

(a) 2.50 (b) 1.50
(c) 1.67 (d) 2.00

23. The activity of a radioactive sample is 6000 Bq after 280 days. After another 140 days, the activity reduces to 3000 Bq. The initial activity of the sample is found to be

(a) 6000 Bq (b) 9000 Bq
(c) 24 000 Bq (d) 3000 Bq

24. The energy of a photon is equal to the kinetic energy of a proton. Let the energy of the photon be E. If λ_1 and λ_2 are respectively the de Broglie wavelength of the proton and the wavelength of the photon, the ratio $\frac{\lambda_1}{\lambda_2}$ will be proportional to

(a) $E°$ (b) $E^{1/2}$ (c) E^{-1} (d) E^{-2}

• *Subjective Type* •

Solve the following problems.

25. The standard free energy change for the reaction

$$H_2(g, 1\text{ atm}) + \frac{1}{2}O_2(g, 1\text{ atm}) \rightarrow H_2O(l)$$

is –240 kJ at 298 K.

(i) Write the galvanic cell which represents the cell reaction

$$H_2(g, 1\text{ atm}) + \frac{1}{2}O_2(g, 1\text{ atm}) \rightarrow H_2O(l).$$

(ii) Determine the standard reduction potential for the electrode $OH^-, O_2 \mid Pt$, given that the cell potential for the reaction

$$H_2O(l) \rightarrow H^+ + OH^-$$

is $E° = -0.6$ V.

26. The freezing point of an aqueous solution of 0.1892 mol kg^{-1} KCN is –0.704°C. The freezing point, however, becomes –0.53°C on adding 0.095 mol $Hg(CN)_2$. Assume that the complex is formed according to the equation

$$Hg(CN)_2 + nCN^- \rightarrow [Hg(CN)_{n+2}]^{n-}.$$

Find the formula of the complex formed.

27. Auric hydroxide dissolves in hydrochloric acid according to the thermochemical equation

$$Au(OH)_3 + 4HCl \xrightarrow{\Delta H} HAuCl_4 + 3H_2O;\ \Delta H° = -23\text{ kcal}$$

and in hydrobromic acid according to the equation

$$Au(OH)_3 + 4HBr \xrightarrow{\Delta H} HAuBr_4 + 3H_2O;\ \Delta H° = -36.8\text{ kcal}.$$

On mixing 1 mol $HAuBr_4$ with 4 mol HCl, there is a heat of absorption of 510 cal. What percentage of bromoauric acid has been transformed into chloroauric acid in the process?

28. The emf of cell

$$Ag(s) \mid AgNO_3(0.01\text{ M}) \parallel AgNO_3(0.001\text{ M}) \mid Ag$$

is 0.0579 V at 25°C. The 0.001-M $AgNO_3$ solution is completely dissociated. Calculate the degree of dissociation and the concentration of Ag^+ in the 0.01-M $AgNO_3$ solution.

29. An ideal gas is initially at a temperature T and with a volume V. Its volume is increased by ΔV due to the increase in temperature, ΔT, pressure remaining constant. The quantity δ is defined by $\delta = \Delta V/V\Delta T$. Establish the relation between δ and T.

30. Given that the second dissociation constant for H_2SO_4 is 10^{-2} mol L^{-1}, calculate the pH of a 0.1-M H_2SO_4 solution.

31. Calculate the cell potential of a Daniell cell having 1.0 M Zn^{2+} and originally having 1.0 M Cu^{2+} after sufficient NH_3 has been added to the cathode compartment to make the NH_3 concentration 2.0 mol L^{-1} (given that $E^{\circ}_{Zn^{2+}|Zn} = -0.76$ V, $E^{\circ}_{Cu^{2+}|Cu} = +0.34$ V, and K_{forward} for $Cu(NH_3)_4^{2+}$ is 1.0×10^{12} mol^{-4} L^4).

32. AB crystallizes in the rock-salt structure, with A : B = 1 : 1. The shortest distance between A and B is $Y^{1/3}$ nm and the formula mass of AB is 6.022 Y u, where Y is any arbitrary constant. Find the density of crystal AB.

33. For the galvanic cell

$$Ag(s)\,|\,AgCl(s),\,NaCl(0.2\text{ M})\,||\,NaBr(0.02\text{ M}),\,AgBr(s)\,|\,Ag,$$

calculate the emf of the cell at 25°C and assign correct polarity, given that $K_s(AgCl) = 2.8 \times 10^{-10}$ (mol $L^{-1})^2$ and $K_s(AgBr) = 3.3 \times 10^{-13}$ (mol $L^{-1})^2$.

34. Find the quantum number n corresponding to the excited state of an He^+ ion if on transition to the ground state the ion emits two photons in succession with the wavelengths 108.5 nm and 30.4 nm respectively.

35. What amount of heat is to be transferred to oxygen in an isobaric heating process so that the gas may perform 2 J work (given that $\gamma = 1.4$ for O_2)?

36. Calculate the order of the rate-determining step in the pyrolysis of $B_2H_6(g)$ at 100°C from the following data.

Concentration of B_2H_6 (in 10^2 mol L^{-1})	**Rate of increase of pressure (in 10^4 mol L^{-1} h^{-1})**
2.153	7.40
0.433	0.73

37. In the reaction

$$2N_2O_5 \rightarrow 4NO_2 + O_2,$$

the rate can be expressed as

(i) $-\dfrac{d[N_2O_5]}{dt} = k_1[N_2O_5]$

(ii) $\dfrac{d[NO_2]}{dt} = k_2[N_2O_5]$

(iii) $\dfrac{d[O_2]}{dt} = k_3[N_2O_5]$

How are k_1, k_2 and k_3 related?

38. 5 mol of an ideal gas expands isothermally and reversibly from a pressure of 10 atm to 2 atm at 300 K. What is the largest mass which can be lifted through a height of 1 m in this expansion?

39. Hydrogen iodide is very strongly adsorbed on gold but slightly adsorbed on platinum. Assume that the adsorption shows the Langmuir isotherm and predict the order of the HI decomposition reaction on each of the two metal surfaces.

40. KCN, which crystallizes in the rock-salt structure, has a density of 1.52 g cm^{-3}. Calculate d_{100} for the unit cell.

Answers

1. d	**2.** b	**3.** c	**4.** b
5. b	**6.** a	**7.** d	**8.** a
9. b	**10.** d	**11.** c	**12.** c
13. b	**14.** d	**15.** b	**16.** b
17. b	**18.** d	**19.** a	**20.** d
21. d	**22.** b	**23.** c	**24.** b
25. (ii) +0.643 V	**26.** $[Hg(CN)_4]^{2-}$	**27.** 3.7	**28.** 96%; 9.6×10^{-3} mol L^{-1}
29. $\delta = \frac{1}{T}$	**30.** 0.9	**31.** 0.70 V	**32.** 5 kg m^{-3}
33. –0.0549 V	**34.** 5	**35.** 7 J	**36.** $\frac{3}{2}$
37. $2k_1 = k_2 = 4k_3$	**38.** 205 kg	**39.** 0; 1	**40.** 6.57 Å

Hints to More Difficult Problems

1.

$$\begin{array}{l} I_2(s) + 2e \rightleftharpoons 2I^-;\ E^\circ = +0.5355\ \text{V} \\ 3I^- \rightleftharpoons I_3^- + 2e;\ E^\circ = -0.5365\ \text{V} \\ \hline I_2(s) + I^- \rightleftharpoons I_3^-;\ E^\circ = -0.0010\ \text{V} \\ \hline \end{array}$$

As we know, $\Delta G^\circ = -nE^\circ F = -RT \ln K_{eq}$.

$$\therefore \quad \log K_{eq} = \frac{nE^\circ}{0.0592} = \frac{2(-0.0010)}{0.0592} = 3.34 \times 10^{-2}.$$

$$\therefore \quad K_{eq} = 0.925.$$

$$\begin{array}{llll} I_2(s) & +I^- & \rightleftharpoons & I_3^- \qquad K_{eq} = 0.925 = \dfrac{x}{0.5 - x} \\ - & 0.5 - x & & x \qquad \therefore \quad x = 0.24\ \text{mol L}^{-1}. \end{array}$$

2. We know that $T_b = \frac{2}{3} T_c$, where T_b is the boiling point at 1 atm and T_c the critical temperature.

$$\therefore \quad T_c = \frac{3}{2} T_b = \frac{3}{2}(273.15\ \text{K} + 68.9\ \text{K}) \approx 513\ \text{K}.$$

3. $$\frac{1}{d_{hkl}^2} = \frac{h^2}{a^2} + \frac{k^2}{b^2} + \frac{l^2}{c^2} = \frac{2^2}{(487\ \text{pm})^2} + \frac{2^2}{(646\ \text{pm})^2} + \frac{2^2}{(415\ \text{pm})^2}$$

$$= 2^2(4.216 \times 10^{-6} + 2.396 \times 10^{-6} + 5.8055 \times 10^{-5})\ \text{pm}^{-2}$$

$$= 64.667 \times 10^{-6}\ \text{pm}^{-2}.$$

$$\therefore \quad \frac{1}{d_{hkl}} \approx 8 \times 10^{-3}\ \text{pm}^{-1}.$$

Therefore, the separation of the {222} planes is given by

$$d_{hkl} = \frac{1}{8} \times 10^{3}\ \text{pm} = 125\ \text{pm}.$$

4. The radius of NaCl is given by

$$r_{\text{NaCl}} = r_{\text{Na}^+} + r_{\text{Cl}^-}$$
$$= (0.55 + 1.81)\ \text{Å} = 2.36\ \text{Å} = 2.36 \times 10^{-10}\ \text{m}.$$

$\therefore$ the dipole moment of NaCl will be

$$\mu = e \times r = (1.602 \times 10^{-19}\ \text{C}) \times (2.36 \times 10^{-10}\ \text{m})$$
$$\approx 3.78 \times 10^{-29}\ \text{C m}.$$

5. $K_b = \dfrac{RT_b^2}{1000L_{\text{vap}}} = \dfrac{RT_b}{1000L_{\text{vap}}/T_b} = \dfrac{RT_b}{s}$

$$= \frac{0.002 \times 373}{1.448} = 0.52\ \text{K kg mol}^{-1}.$$

$$\Sigma n = n_{\text{glucose}} + n_{\text{urea}} = \frac{90}{180} + \frac{45}{60} = 1.25;\ \ m = 1.25\ \text{mol kg}^{-1}.$$

$$\Delta T_b = K_b \cdot m = 0.52\ \text{K kg mol}^{-1} \times 1.25\ \text{mol kg}^{-1} = 0.65\ \text{K}.$$

6. $n = \dfrac{pV}{RT} = \dfrac{1.00\ \text{atm} \times (3 \times 10^{-3})\ \text{L}}{0.0821\ \text{L atm K}^{-1}\ \text{mol}^{-1} \times 273\ \text{K}} = 1.3385 \times 10^{-4}\ \text{mol}.$

$$N = nN_A = (1.3385 \times 10^{-4})\ \text{mol} \times (6.02 \times 10^{23})\ \text{mol}^{-1} = 8.06 \times 10^{19}.$$

$$A = 8.06 \times 10^{19} \times 0.2 \times 10^{-18}\ \text{m}^2 = 16.12\ \text{m}^2.$$

7. $Z = \dfrac{pV}{nRT} \ \Rightarrow\ V = Z \cdot \dfrac{nRT}{p} = 0.111\,93\ \text{L}.$

For negligible volume, $\left(p + \dfrac{a}{(V/n)^2}\right) \cdot \dfrac{V}{n} = RT.$

Upon proper substitution, we have $a = 1.253\ \text{atm L}^2\ \text{mol}^{-2}$.

8. The first Lyman line for He^+

$$\bar{\nu} = R_\infty Z^2 \left(\frac{1}{m^2} - \frac{1}{n^2}\right) = R_\infty \cdot 4 \cdot \left(\frac{1}{1} - \frac{1}{4}\right) = \frac{3}{R_\infty}$$

The first Balmer series for He^+

$$\bar{\nu} = R_\infty 2^2 \left(\frac{1}{2^2} - \frac{1}{3^2}\right) \text{ and } \lambda_A = \frac{1}{3} \cdot \frac{1}{R_\infty},\ \lambda_B = \frac{9}{5} \cdot \frac{1}{R_\infty}$$

$$\Delta\lambda = \lambda_B - \lambda_A = \left(\frac{9}{5} - \frac{1}{3}\right)\frac{1}{R_\infty}$$

$$\therefore \quad 133.7 \times 10^{-9}\ \text{m} = \frac{22}{15} \cdot \frac{1}{R_\infty} \ \Rightarrow\ R_\infty = 1.097 \times 10^{7}\ \text{m}^{-1}.$$

9. From the $KMnO_4$ titration,
amount of e reacted = 48 mL × 0.1 mol L^{-1} = 4.80 mmol.

$$C_2O_4^{2-} \rightleftharpoons 2CO_2 + 2e$$

Amount of oxalate reacted $= \frac{4.80}{2}$ mmol = 2.40 mmol.
From the KOH titration,
amount H^+ in sample = 18 mL × 0.08 mol L^{-1} = 1.44 mmol.

Hence, the fraction of oxalate protonated is $\frac{1.44}{2.40} = 0.60$.

10. $K_{300\,K} = \frac{1}{t_1} \ln \frac{100}{100-20}$ and $K_{310\,K} = \frac{1}{t_2} \ln \frac{100}{100-30}$

Given $t_1 = 1.5t_2$; $\frac{K_{300\,K}}{K_{310\,K}} = 0.417$

$$\ln \frac{K_2}{K_1} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right) \Rightarrow \ln 0.417 = -\frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$E_a = 67.6 \text{ kJ mol}^{-1}$$

$$\ln k = \ln A - \frac{E_a}{RT} = \ln (3 \times 10^9) - \frac{67.6 \times 10^3}{8.314 \times 320}$$

$$k = 0.027 \text{ s}^{-1}$$

$$t = \frac{1}{0.027 \text{ s}^{-1}} \ln \frac{100}{100-40} = 19 \text{ s}.$$

11. The cell reactions are as follows:

Anode: $2Hg(l) + SO_4^{2-} \rightarrow Hg_2SO_4(s)$; $E° = -0.62$ V

Cathode: $PbSO_4(s) + 2e \rightarrow Pb(s) + SO_4^{2-}$; $E° = -0.36$ V

$$2Hg(l) + PbSO_4(s) \rightarrow Pb(s) + Hg_2SO_4;\ E° = -0.98 \text{ V}$$

$$PbSO_4 = Pb^{2+} + SO_4^{2-} \text{ and } Hg_2SO_4 = Hg_2^{2+} + SO_4^{2-}$$

Using the Nernst equation,

$$E = (E°_{PbSO_4/Pb,\, SO_4^{2-}} - E°_{Hg_2SO_4/Hg,\, SO_4^{2-}}) - \frac{0.0592}{2} \log \frac{[Hg_2SO_4]}{[PbSO_4]}$$

$$-0.932 = -0.98 - \frac{0.0592}{2} \log \frac{[Hg^+]^2[SO_4^{2-}]}{[Pb^{2+}][SO_4^{2-}]}$$

$$-0.932 = -0.98 - \frac{0.0592}{2} \log \frac{K_s(Hg_2SO_4)}{K_s(PbSO_4)}$$

$$= -0.98 - \frac{0.0592}{2} \log \frac{1.6 \times 10^{-8} \text{ (mol L}^{-1})^3}{K_s(PbSO_4)}$$

$$K_s(PbSO_4) = 6.6 \times 10^{-7} \text{ (mol L}^{-1})^2.$$

12. In the RbBr molecule, the Rb^+ and Br^- ions have equal (36) number of electrons. Thus these two ions diffract (or 'reflect') X-rays in the similar way. As these ions are identical, an RbBr crystal appears to be simple cubic, whereas the other three crystals have the face-centred cubic structure.

13. $\Lambda = \dfrac{1000\kappa}{c} = \dfrac{1000 \times 5.55 \times 10^{-8}\ \Omega^{-1}\ \text{cm}^{-1}}{55.5\ \text{mol cm}^{-3}} = 10^{-6}\ \Omega^{-1}\ \text{cm}^2\ \text{mol}^{-1}.$

$\Lambda^\circ = \lambda^\circ_{H^+} + \lambda^\circ_{OH^-} = (350 + 200)\ \Omega^{-1}\ \text{cm}^2\ \text{mol}^{-1} = 550\ \Omega^{-1}\ \text{cm}^2\ \text{mol}^{-1}.$

$\alpha = \dfrac{\Lambda}{\Lambda^\circ} = \dfrac{10^{-6}}{550} = 1.8 \times 10^{-9}.$

$\underset{}{H_2O} \rightleftharpoons \underset{\alpha c}{H^+} + \underset{\alpha c}{OH^-} \qquad K_w = [H^+][OH]$

$K_w = (1.8 \times 10^{-9} \times 55.5)^2\ (\text{mol L}^{-1})^2 = 1.0 \times 10^{-14}\ (\text{mol L}^{-1})^2.$

14. 1 equivalent Sn $\equiv$ 1 equivalent $K_2Cr_2O_7$

$\dfrac{119}{4}$ g of Sn = 1000 mL N $\qquad \left[Sn \rightarrow Sn^{4+} + 4e;\ E_{Sn} = \dfrac{119}{4} \right]$

$1\ \text{g} \equiv \dfrac{1000}{119/4}$ mL N

According to question $\dfrac{1000}{119/4}$ mL N $= V \times$ N

$\therefore \quad V = 336$ mL.

15. We know that

$$\Delta H^\circ_{diss} + \Delta H_{neut}\ \text{(strong acid and strong base)}$$
$$= \Delta H_{neut}\ \text{(weak acid and strong base)}$$

or $\Delta H^\circ_{diss} - 13\,700\ \text{cal} = -13\,385\ \text{cal}.$

$\therefore \qquad \Delta H^\circ_{diss} = +315\ \text{cal}.$

ΔH°_{diss} per equivalent $= \dfrac{315\ \text{cal}}{86} \times 100 = 366$ cal

$(\underset{(1-\alpha)c}{HA} \rightleftharpoons \underset{\alpha c}{H^+} + \underset{\alpha c}{A^-} \qquad \alpha = 14\%$ and $c = 1$ N)

16. $CH_3COOH \rightleftharpoons H^+ + CH_3COO^- \qquad C_6H_5COOH \rightleftharpoons C_6H_5COO^- + H^+$

$K = \dfrac{[H^+][CH_3COO^-]}{[CH_3COOH]}$ (1)	$K = \dfrac{[H^+][C_6H_5COO^-]}{[C_6H_5COOH]}$ (2)
$[CH_3COOH] = \dfrac{20}{60}$	$[C_6H_5COOH] = \dfrac{10}{122}$
$[H^+] = [CH_3COO^-]$	$[H^+] = [C_6H_5COO^-]$

From (1), $[H^+]^2 = 1.80 \times 10^{-5} \times \dfrac{20}{60}\ (\text{mol L}^{-1})^2.$ (3)

From (2), $[H^+]^2 = 1.80 \times 10^{-6} \times \dfrac{10}{122}\ (\text{mol L}^{-1})^2.$ (4)

From (3) and (4) we get $[H^+] = 3.46 \times 10^{-3}$ mol L^{-1}. $\quad \therefore \quad$ pH = 2.46.

17. $T = \dfrac{2\pi r}{v}$ or $T \propto \dfrac{r}{v}\cdot$

Now, $r \propto n^2$ and $v \propto \dfrac{1}{n}\cdot$

$\therefore \quad T \propto n^3 \Rightarrow T_1 = 8T_2 \Rightarrow n_1 = 2n_2.$

18. The de Broglie wavelength is given by

$$\lambda = \frac{h}{(2m_e eV)^{1/2}}\cdot$$

$$\therefore \qquad \lambda^2 = \frac{h^2}{2m_e eV}\cdot$$

Then the electron must be accelerated through the potential difference

$$V = \frac{h^2}{2\lambda^2 m_e e} = \frac{(6.626\times 10^{-34}\ \mathrm{J\ s})^2}{2(550\ \mathrm{nm})^2(9.109\times 10^{-31}\ \mathrm{kg})(1.602\times 10^{-19}\ \mathrm{C})}$$

$$= \frac{43.903\ 876\times 10^{-68}\ \mathrm{J^2\ s^2}}{2(550\times 10^{-9}\ \mathrm{m})^2(14.592\ 618\times 10^{-50}\ \mathrm{kg\ C})}$$

$$= \frac{43.903\ 876\times 10^{-18}(\mathrm{kg\ m^2\ s^{-2}})^2\ \mathrm{s^2}}{2(302\ 500\times 10^{-18}\ \mathrm{m^2})(14.592\ 618\ \mathrm{kg\ C})}$$

$$= 0.000\ 004\ 97\ \mathrm{kg\ m^2\ s^{-2}\ C^{-1}}$$

$$= 4.97\times 10^{-6}\ \mathrm{J\ C^{-1}} \approx 5\times 10^{-6}\ \mathrm{V}$$

$$= 5\ \mu\mathrm{V}.$$

19. According to the question, the number of atoms per unit cell is $Z = 8$.

Using the formula $\rho = \dfrac{Z\cdot M}{N_A\cdot a^3}$, we have

$$3.515\ \mathrm{g\ cm^{-3}} = \frac{8\times 12\ \mathrm{g\ mol^{-1}}}{(6.022\times 10^{23}\ \mathrm{mol^{-1}})\times a^3}\cdot$$

$\therefore \quad a \approx 356.6$ pm.

20. $\mathrm{HAc} \rightleftharpoons \mathrm{H^+ + Ac^-}$ and $\mathrm{NaAc} \longrightarrow \mathrm{Na^+ + Ac^-}$

$$K_a = \frac{[\mathrm{H^+}][\mathrm{Ac^-}]}{[\mathrm{HAc}]} = \frac{[\mathrm{H^+}]\times 0.1\ \mathrm{mol\ L^{-1}}}{0.1\ \mathrm{mol\ L^{-1}}} = 1.8\times 10^{-5}\ \mathrm{mol\ L^{-1}}.$$

$\therefore \quad [\mathrm{H^+}] = 1.8\times 10^{-5}\ \mathrm{mol\ L^{-1}}.$

$$E_{cell} = E^\circ_{cal} - E^\circ_{H_2} = 0.337\ \mathrm{V} - \frac{0.0592}{1}\log(1.8\times 10^{-5})\ \mathrm{V}$$

$$= (0.337 + 0.281)\ \mathrm{V} = 0.618\ \mathrm{V}.$$

21. For Mechanism A we have

$$v = k[\mathrm{NOH_2}][\mathrm{NO}] \quad \text{and} \quad K = \frac{[\mathrm{NOH_2}]}{[\mathrm{NO}][\mathrm{H_2}]}.$$

$$\therefore \qquad [\mathrm{NOH_2}] = \frac{v}{k[\mathrm{NO}]} = K[\mathrm{NO}][\mathrm{H_2}].$$

$$\therefore \qquad v = Kk[\mathrm{NO}]^2[\mathrm{H_2}].$$

$$\therefore \qquad v \propto [\mathrm{NO}]^2[\mathrm{H_2}]. \qquad (1)$$

For Mechanism B we obtain

$$v' = k'[\mathrm{N_2O_2}][\mathrm{H_2}] \quad \text{and} \quad K' = \frac{[\mathrm{N_2O_2}]}{[\mathrm{NO}]^2}.$$

$$\therefore \qquad [\mathrm{N_2O_2}] = \frac{v'}{k'[\mathrm{H_2}]} = K'[\mathrm{NO}]^2.$$

$$\therefore \qquad v' = K'k'[\mathrm{NO}]^2[\mathrm{H_2}].$$

$$\therefore \qquad v' \propto [\mathrm{NO}]^2[\mathrm{H_2}]. \qquad (2)$$

Now, from (1) and (2) it is clear that the rate of the given reaction is proportional to $[\mathrm{NO}]^2[\mathrm{H_2}]$ for either of the two mechanisms proposed.

22. Let U_1 and U_2 be the internal energies per mole of the monatomic gas and the diatomic gas respectively.

Thus $U_1 = \frac{3}{2}RT$; $U_2 = \frac{5}{2}RT$

$$\text{or} \quad U = \frac{U_1 + U_2}{2} = \frac{\frac{3}{2}RT + \frac{5}{2}RT}{2} = 2RT \quad (\text{Total mole} = 2)$$

$$\text{or} \quad C_v = \left.\frac{\partial U}{\partial T}\right]_v = 2R.$$

We know that $C_p - C_v = R$ or $C_p - 2R = R$ or $C_p = 3R$.

$$\therefore \quad \gamma = \frac{C_p}{C_v} = \frac{3R}{2R} = \frac{3}{2} = 1.5.$$

23. As the activity of the sample reduces from 6000 Bq to 3000 Bq in 140 days, it is clear that the half-life of the sample is $t_{1/2} = 140$ days.

$\therefore$ in $2t_{1/2} = 280$ days, the activity becomes one-fourth of the initial activity.

$\therefore$ the initial activity of the radioactive sample equals

$$4 \times 6000 \text{ Bq} = 24\,000 \text{ Bq}.$$

24. Since the kinetic energy of the proton is E and its de Broglie wavelength is λ_1, we have

$$\lambda_1 = \frac{h}{(2m_\mathrm{p}eV)^{1/2}} = \frac{h}{(2m_\mathrm{p}E)^{1/2}}. \qquad (1)$$

Again, the wavelength of the photon having an energy equal to E is given by

$$\lambda_2 = \frac{hc}{E}. \tag{2}$$

Now, from (1) and (2) we find that

$$\frac{\lambda_1}{\lambda_2} = \frac{\dfrac{h}{(2m_p E)^{1/2}}}{\dfrac{hc}{E}} = \frac{E}{\sqrt{2m_p} \cdot cE^{1/2}} = \frac{E^{1/2}}{\sqrt{2m_p} \cdot c}.$$

As the mass of a proton (m_p) and the speed of light in vacuum (c) are fundamental constants, we conclude that

$$\frac{\lambda_1}{\lambda_2} \propto E^{1/2}.$$

25. (i) The galvanic cell is

$$\overset{-}{\mathrm{Pt}} \mid H_2(\mathrm{g, 1\ atm}) \mid \mathrm{NaOH(1\ M)} \mid O_2(\mathrm{g, 1\ atm}) \overset{+}{\mid} \mathrm{Pt}$$

LHE (ox): $H_2 + 2OH^- \rightarrow 2H_2O + 2e$

RHE (red): $\frac{1}{2} O_2 + H_2O + 2e \rightarrow 2(OH^-)$

Net reaction: $H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(l)$

(ii) $\overset{-}{\mathrm{Pt}} \mid H_2(\mathrm{g, 1\ atm}) \mid H^+ \parallel OH^-, O_2(\mathrm{g, 1\ atm}) \overset{+}{\mid} \mathrm{Pt}$

LHE (ox): $H_2(g) \rightarrow 2H^+ + 2e$

RHE (red): $\frac{1}{2} O_2 + H_2O + 2e \rightarrow 2(OH^-)$

Net reaction: $H_2 + \frac{1}{2} O_2 + H_2O \rightarrow 2H^+ + 2(OH^-)$

For the reaction $H_2O(l) \rightleftharpoons H^+ + OH^-$,

$$\Delta G^\circ = -nFE^\circ = -(1)\ (96\,500\ \mathrm{C\ mol^{-1}})(-0.6\ \mathrm{V}) = 57.9\ \mathrm{kJ\ mol^{-1}}.$$

For the reaction $H_2 + \frac{1}{2} O_2 + 2H_2O \rightarrow H_2O + 2H^+ + 2OH^-$,

$$\Delta G_r^\circ = \Delta_{\mathrm{formation}}\, G^\circ_{H_2O} + 2\Delta_{\mathrm{ions}}\, G^\circ_{H_2O}$$

$$= 57.9 \times 2 - 240 = -124.2\ \mathrm{kJ}$$

$$E^\circ_{\mathrm{cell}} = -\frac{\Delta G^\circ}{nF} = \frac{124.2 \times 10^3}{2 \times 96\,500} = 0.643\ \mathrm{V}.$$

Thus, $E^\circ_{\mathrm{cell}} = E^\circ_{\mathrm{red}} \mid OH^- \mid O_2, \mathrm{Pt} - E^\circ_{H^+ \mid H_2} = E^\circ_{\mathrm{cell}} \mid OH^- \mid O_2 \mid \mathrm{Pt} = 0.643\ \mathrm{V}.$

26. The equilibrium composition of the given reaction is given below.

Equation:	$Hg(CN)_2$	+	nCN^-	$\longrightarrow$	$[Hg(CN)_{n+2}]^{n-}$
Initial amounts:	0.095 mol		0.1892 mol		0 mol
Changes to reach equilibrium:	–0.095 mol		–0.095n mol		+0.095 mol
Amounts at equilibrium:	0 mol		(0.1892–0.095n) mol		0.095 mol

Hence, the total molality obtained after the addition of $Hg(CN)_2$ is

$$m_{\text{total}} = m(K^+) + m(CN^-) + m([Hg(CN)_{n+2}]^{n-})$$
$$= 0.1892 \text{ mol kg}^{-1} + (0.1892 - 0.095n) \text{ mol kg}^{-1} + 0.095 \text{ mol kg}^{-1}$$
$$= (0.4734 - 0.095n) \text{ mol kg}^{-1}.$$

Since the freezing point of pure water is 0°C and that of the aqueous solution of KCN is –0.704°C, the depression of freezing point of water on adding KCN is $\Delta T_{f,\,KCN} = 0°C - (-0.704°C) = 0.704°C$.

Also, the van't Hoff factor for KCN is $i \approx 2$ as the solute dissociates almost completely.

∴ the freezing-point constant is given by

$$K_f = \frac{\Delta T_{f,\,KCN}}{m(KCN)\cdot i} = \frac{0.704}{0.1892 \times 2} \text{ K kg mol}^{-1} \approx 1.86 \text{ K kg mol}^{-1}.$$

Now, the depression of freezing point of water on adding $Hg(CN)_2$ is given by

$$\Delta T_{f,\,Hg(CN)_2} = K_f \cdot m_{\text{total}}.$$

$$\therefore \quad 0°C - (-0.53°C) = (1.86 \text{ K kg mol}^{-1}) \cdot (0.4734 - 0.095n) \text{ mol kg}^{-1}$$

$$\Rightarrow \quad 0.53 \text{ K} = (0.880\,524 - 0.1767n) \text{ K}$$

$$\Rightarrow \quad 0.1767n = 0.880\,524 - 0.53 = 0.350\,524.$$

$$\therefore \quad n = \frac{0.350\,524}{0.1767} = 1.9837\ldots \approx 2.$$

Therefore the formula of the complex formed is found to be $[Hg(CN)_4]^{2-}$.

27. The ratio of the quantity of bromoauric acid transformed into chloroauric acid to the total quantity of bromoauric acid employed is equal to the ratio of the observed heat of evolution to the molar heat of the reaction

$$HAuBr_4 + 4HCl \rightarrow HAuCl_4 + 4HBr.$$

The molar heat of this reaction is obtained as follows by subtracting equation (2) from equation (1), giving equation (3):

$$Au(OH)_3 + 4HCl = HAuCl_4 + 3H_2O;\ \Delta H° = -23.00 \text{ kcal} \quad (1)$$
$$Au(OH)_3 + 4HBr = HAuBr_4 + 3H_2O;\ \Delta H° = -36.8 \text{ kcal} \quad (2)$$
$$HAuBr_4 + 4HCl = HAuCl_4 + 4HBr;\ \Delta H° = +13.8 \text{ kcal} \quad (3)$$

Let x% bromoauric acid be transformed into chloroauric acid.

$$\therefore \quad \frac{x}{100} = \frac{0.51 \text{ kcal}}{1.38 \text{ kcal}} \quad \Rightarrow \quad x \approx 3.7.$$

28. The emf of concentration cell is

$$E = -\frac{0.0592}{n} \log \frac{a_L}{a_R}$$

$$\text{or} \qquad 0.0579 = -\frac{0.0592}{1} \log \frac{0.001\alpha_1}{0.01\alpha_2} \cdot$$

$$\text{or} \qquad 0.0579 = -\frac{0.0592}{1} \log \frac{0.001 \times 1}{0.01\alpha_2}$$

$$\therefore \qquad \alpha_2 = 0.96 = 96\%.$$

$$\therefore \qquad [Ag^+] = 0.01 \text{ mol L}^{-1} \times \alpha_2 = 9.6 \times 10^{-3} \text{ mol L}^{-1}.$$

29. Use the ideal gas equation, i.e. $pV = nRT$. (1)

Differentiating both sides w.r.t. T at constant pressure, we get

$$p\frac{dV}{dT} = nR. \qquad (2)$$

Dividing (2) by (1),

$$\frac{1}{V}\frac{dV}{dT} = \frac{1}{T} \quad \text{or} \quad \delta = \frac{1}{T} \cdot$$

30. The dissociation of H_2SO_4 takes place in the following steps.

Step I: $\qquad H_2SO_4 \xrightarrow{K_1} H^+ + HSO_4^-$

Step II: $\qquad HSO_4^- \overset{K_2}{\rightleftharpoons} H^+ + SO_4^{2-}$

Now, consider the equilibrium composition of Step II as shown below.

Equation:	HSO_4^-	$\longrightarrow$	H^+	+	SO_4^{2-}
Initial amounts:	0.1 mol		0 mol		0 mol
Changes to reach equilibrium:	$-x$ mol		$+x$ mol		$+x$ mol
Amounts at equilibrium:	$(0.1 - x)$ mol		x mol		x mol

Hence, we have

$$K_2 = \frac{[H^+][SO_4^{2-}]}{[HSO_4^-]} = \frac{(x \text{ mol L}^{-1})(x \text{ mol L}^{-1})}{(0.1 - x) \text{ mol L}^{-1}} \cdot$$

$$\therefore \qquad 10^{-2} \text{ mol L}^{-1} = \frac{x^2 (\text{mol L}^{-1})^2}{(0.1 - x) \text{ mol L}^{-1}}$$

$$\Rightarrow \qquad x^2 = 10^{-2}(0.1 - x) = 0.001 - 0.01x$$

$$\Rightarrow \qquad x^2 + 0.01x - 0.001 = 0.$$

$$\therefore \qquad (x - 0.027)(x + 0.037) \approx 0.$$

Since x cannot be negative, $x \approx 0.027$.

$$\therefore \qquad [H^+]_{total} = [H^+]_{H_2SO_4} + [H^+]_{HSO_4^-}$$
$$= (0.1 + x)\ \text{mol L}^{-1}$$
$$= (0.1 + 0.027)\ \text{mol L}^{-1} = 0.127\ \text{mol L}^{-1}.$$
$$\therefore \qquad \text{pH} = -\log 0.127 = -(-0.896\ 19\ldots) \approx 0.9.$$

31. The cell is $Zn(s)\,|\,Zn^{2+}(1\ M)\,||\,Cu^{2+}(1\ M)\,|\,Cu(s) + NH_3(\text{excess})$

$$Cu^{2+} + 4NH_3 \rightleftharpoons Cu(NH_3)_4^{2+} \qquad K_f = \frac{[Cu(NH_3)_4^{2+}]}{[NH_3]^4[Cu^{2+}]}$$

Initially, 1.0 M excess 0

At equilibrium, $(1-x)$ 2.0 M x $\quad 1.0 \times 10^{-12} = \dfrac{x}{2^4(1-x)}$

$$\frac{x}{1-x} = 16 \times 10^{-12} \quad \Rightarrow \quad \frac{1-x}{x} = \frac{1}{16 \times 10^{-12}} \quad \Rightarrow \quad \frac{1}{x} - 1 = \frac{1}{16 \times 10^{-12}}.$$

$$\frac{1}{x} = \frac{1}{16 \times 10^{-12}} \quad \Rightarrow \quad x = 16 \times 10^{-12}.$$

$$E_{cell} = (E_R^\circ - E_L^\circ) - \frac{0.0592}{2}\log\frac{[Zn^{2+}]}{[Cu^{2+}]}\ \text{V}$$
$$= 1.10\ \text{V} - 0.0296\log\frac{1.0}{16 \times 10^{-12}}\ \text{V}$$
$$= 1.10\ \text{V} - 0.0296(-\log 2^4 + 12)\ \text{V}.$$
$$\therefore \quad E_{cell} = 0.70\ \text{V}.$$

32. Since the crystal is fcc, the edge length of the unit cell is $a = 2 \times$ shortest distance between A and B $= 2Y^{1/3}$ nm.

As we know, $$\rho = \frac{Z \cdot M}{N_A \cdot a^3} = \frac{4 \times 6.022Y\ \text{u mol}^{-1}}{(6.022 \times 10^{23}\ \text{mol}^{-1})(2Y^{1/3} \times 10^{-9}\ \text{m})^3}$$
$$= 0.5 \times 10^4\ \text{u m}^{-3} = 0.83 \times 10^{-23}\ \text{kg m}^{-3}.$$

33. $$E_{cell} = \frac{0.0592}{1}\log\frac{K_s(AgBr/Br^-)}{K_s(AgCl/Cl^-)}\ \text{V}$$
$$= \frac{0.0592}{1}\log\frac{3.3 \times 10^{-13}/0.02}{2.8 \times 10^{-10}/0.2}\ \text{V}$$
$$= -0.115\ \text{V}.$$

Since E_{cell} is negative, the reverse reaction is spontaneous.

34. $$\lambda_1 = 108.5\ \text{nm} = 108.5 \times 10^{-9}\ \text{m}$$
$$\lambda_2 = 30.4\ \text{nm} = 30.4 \times 10^{-9}\ \text{m}$$

Let the excited state be n_2. The electron falls first from n_2 to n_1 and then from n_1 to the ground state.

$$\frac{1}{\lambda_2} = Z^2 R_\infty \left(\frac{1}{1^2} - \frac{1}{n_1^2} \right)$$

or $$\frac{1}{30.4 \times 10^{-9}\ \mathrm{m}} = 2^2 \times (1.097 \times 10^7\ \mathrm{m}^{-1}) \times \left(\frac{1}{1^2} - \frac{1}{n_1^2} \right)$$

or $$n_1 = 2.$$

Again, $$\frac{1}{\lambda_1} = Z^2 R_\infty \left(\frac{1}{2^2} - \frac{1}{n_2^2} \right)$$

or $$\frac{1}{108.5 \times 10^{-9}\ \mathrm{m}} = 2^2 \times (1.097 \times 10^7\ \mathrm{m}^{-1}) \times \left(\frac{1}{2^2} - \frac{1}{n_2^2} \right)$$

or $$n_2 = 5.$$

35. We know that $\Delta U = \dfrac{p\Delta V}{\gamma - 1}$.

At constant pressure, $dw = p\Delta V$. (1)

From (1) and (2),

$$\Delta U = \frac{dw}{\gamma - 1} \text{ or } \Delta U = dq - dw \text{ or } dq = \Delta U + dw = \frac{dw}{\gamma - 1} + 1.$$

$$\therefore \quad dq = \frac{\gamma}{\gamma - 1} dw = \frac{1.4}{1.4 - 1} \times 2\ \mathrm{J} = \frac{2.8}{0.4}\ \mathrm{J} = 7\ \mathrm{J}.$$

36. Let the order of the rate-determining step in the pyrolysis of $B_2H_6(g)$ be n. Then the rate law for the reaction is

$$v = k[B_2H_6]^n.$$

Hence, from the given data we obtain

$$7.40 \times 10^4\ \mathrm{mol\ L^{-1}\ h^{-1}} = k(2.153 \times 10^2\ \mathrm{mol\ L^{-1}})^n \quad (1)$$

and

$$0.73 \times 10^4\ \mathrm{mol\ L^{-1}\ h^{-1}} = k(0.433 \times 10^2\ \mathrm{mol\ L^{-1}})^n \quad (2)$$

Now, dividing (1) by (2),

$$\frac{7.40}{0.73} = \left(\frac{2.153}{0.433} \right)^n$$

$$\therefore \quad \log \frac{7.40}{0.73} = \log \left(\frac{2.153}{0.433} \right)^n$$

$$\Rightarrow \quad \log 10.137 = n \log 4.972.$$

$$\therefore \quad n = \frac{\log 10.137}{\log 4.972} \approx \frac{1.006}{0.696}$$

$$\approx 1.4454\ldots \approx 1.5 = \frac{3}{2}.$$

37. The rate law of the given reaction is

$$\text{rate} = -\frac{1}{2}\frac{d[N_2O_5]}{dt} = \frac{1}{4}\times\frac{d[NO_2]}{dt} = \frac{d[O_2]}{dt} = k[N_2O_5].$$

$$\frac{d[N_2O_5]}{dt} = 2k[N_2O_5] = k_1[N_2O_5] \quad \text{or} \quad 2k = k_1 \quad \text{or} \quad 4k = 2k_1.$$

$$\frac{d[NO_2]}{dt} = 4k[N_2O_5] = k_2[N_2O_5] \quad \text{or} \quad 4k = k_2 \quad \text{or} \quad 4k = k_2.$$

$$\frac{d[O_2]}{dt} = k[N_2O_5] = k_3[N_2O_5] \quad \text{or} \quad k = k_3 \quad \text{or} \quad 4k = 4k_3.$$

The relation is $2k_1 = k_2 = 4k_3$.

38. Work done by the system $(w) = -nRT \ln \dfrac{p_1}{p_2}\cdot$

$$w = -2.303\ nRT \log\frac{p_1}{p_2} = -2.303\times 5\times 8.314\times 300 \log\frac{10}{2}$$

$$= -2.0075\times 10^4\ \text{J}.$$

Let m be the mass which can be lifted through a height of 1 m.

$w = mgh$ or $2.0075\times 10^4\ \text{J} = m\times 9.8\times 1\ \text{J}$

$\therefore$ $m = 205$ kg (approx.)

39. Rate $= v = K\theta = \dfrac{kKp}{1+Kp}\cdot$

(a) Adsorption on gold is $\theta \approx 1$, and $v = K =$ constant.

Hence, it is a zero-order reaction.

(b) Adsorption on platinum is $\theta \approx K_p$ as $K_p < 1$.

So $v = kKp$, and the reaction is of the first order.

40. The formula weight of KCN is equal to

$$M_r = 39.1 + 12 + 14 = 65.1.$$

$\therefore$ the molar mass is given by

$$M = 65.1\ \text{g mol}^{-1}.$$

$\therefore$ molar volume, $V_m = \dfrac{M}{\rho} = \dfrac{65.1\ \text{g mol}^{-1}}{1.52\ \text{g cm}^{-3}} \approx 42.8289\ \text{cm}^3\ \text{mol}^{-1}.$

$\therefore$ the volume of a formula unit is

$$V = \frac{V_m}{N_A} = \frac{42.8289\ \text{cm}^3\ \text{mol}^{-1}}{6.022\times 10^{23}\ \text{mol}^{-1}}$$

$$\approx 7.112\,07\times 10^{-23}\ \text{cm}^3$$

$$= 71.1207\times 10^{-24}\ \text{cm}^3.$$

Since the rock-salt structure is a face-centred cubic crystal containing four formula units, the volume of the unit cell equals

$$a^3 = 4V = 4(71.1207\times 10^{-24}\ \text{cm}^3)$$

$$= 284.4828\times 10^{-24}\ \text{cm}^3.$$

$$\therefore \qquad a = (284.4828 \times 10^{-24}\ \text{cm}^3)^{1/3}$$
$$= (284.4828)^{1/3} \times 10^{-8}\ \text{cm}$$
$$= (284.4828)^{1/3} \times 10^{-10}\ \text{m}$$
$$= (284.4828)^{1/3}\text{Å}.$$

$$\therefore \qquad d_{100} = \frac{a}{(1^2 + 0^2 + 0^2)^{1/2}} = (284.4828)^{1/3}\ \text{Å}.$$

$$\therefore \qquad \ln d_{100} = \frac{1}{3}(\ln 284.4828)\ \text{Å} \approx \frac{5.6507}{3}\ \text{Å} \approx 1.883\ \text{Å}.$$

$$\therefore \qquad d_{100} = (\exp 1.883)\ \text{Å} \approx 6.57\ \text{Å}.$$

❑

Part 2

Inorganic Chemistry

1

Periodic Table

• *Type 1* •

Choose the correct option. Only one option is correct.

1. The correct order of increasing radius of the elements Si, Al, Na and P is

(a) Si, Al, P, Na (b) P, Si, Al, Na

(c) Al, Si, P, Na (d) Al, P, Si, Na

2. Which of the following series of elements have nearly the same atomic radii?

(a) F, Cl, Br, I (b) Na, K, Rb, Cs

(c) Li, Be, B, C (d) Fe, Co, Ni, Cu

3. In which of the following pairs is the second atom larger than the first?

(a) Br, Cl (b) Na, Mg

(c) Sr, Ca (d) N, P

4. Which of the following compounds may one expect to be strongly ionic in character?

(a) $BaCl_2$ (b) CsCl (c) $CaCl_2$ (d) $SrCl_2$

5. The order of increasing electron affinity of the electronic configurations

(i) $1s^2 2s^2 2p^6 3s^2 3p^5$ (ii) $1s^2 2s^2 2p^3$

(iii) $1s^2 2s^2 2p^5$ (iv) $1s^2 2s^2 2p^6 3s^1$

is

(a) (ii), (iv), (iii), (i) (b) (i), (ii), (iii), (iv)

(c) (i), (iii), (ii), (iv) (d) (iv), (iii), (ii), (i)

6. The highest ionization energy is exhibited by

(a) halogens (b) alkaline earth metals

(c) transition metals (d) noble gases

7. Which among the following electronic configurations represents the element with the maximum electron affinity?

(a) $1s^2 2s^2 2p^6$ (b) $1s^2 2s^2 2p^5$

(c) $1s^2 2s^2 2p^6 3s^1$ (d) $1s^2 2s^2 2p^6 3s^2 3p^5$

8. In which of the following pairs does one element exist as a solid and the other as a liquid under normal conditions?

(a) I_2 and F_2 (b) I_2 and Br_2

(c) Br_2 and Hg (d) Na and Cs

9. Among the following, the element which has the configuration

(a) [Ne] $3s^1 3p^2$ (b) [Ne] $3s^2 3p^5$

(c) [Ne] $3s^2 3p^4$ (d) [Ne] $3s^2 3p^6 3d^5 4s^1$

has the highest electron affinity.

10. Which of the following sets of atomic numbers corresponds to elements of group 16?

(a) 8, 16, 32, 54 (b) 16, 34, 54, 86

(c) 8, 16, 34, 52 (d) 10, 16, 32, 50

11. Among the following electronic configurations, the one corresponding to the element with the highest ionization energy is

(a) [Ne] $3s^2 3p^1$ (b) [Ar] $3d^{10} 4s^2 4p^2$

(c) [Ne] $3s^2 3p^2$ (d) [Ne] $3s^2 3p^3$

12. Of which of the following elements is the first ionization energy the lowest?

(a) Lead (b) Carbon (c) Silicon (d) Tin

13. Among the following elements, which has the highest ionization energy?

(a) Nitrogen (b) Chromium

(c) Neon (d) Manganese

14. The thermal stability of $BaCO_3$, $CaCO_3$, $SrCO_3$ and $MgCO_3$ decreases in the order

(a) $BaCO_3 > SrCO_3 > MgCO_3 > CaCO_3$

(b) $CaCO_3 > SrCO_3 > MgCO_3 > BaCO_3$

(c) $MgCO_3 > CaCO_3 > SrCO_3 > BaCO_3$

(d) $BaCO_3 > SrCO_3 > CaCO_3 > MgCO_3$

15. Which of the following has the maximum number of unpaired electrons?

(a) Ti^{3+} (b) V^{3+}

(c) Fe^{3+} (d) Fe^{2+}

16. If the aufbau principle had not been followed, Ca($Z = 20$) would have been placed in the

(a) s-block (b) p-block
(c) d-block (d) f-block

17. Among the equations given below, the one whose $\Delta H°$ value equals the first ionization energy of Ca is

(a) $Ca^{+}(g) \longrightarrow Ca^{2+}(g) + e$ (b) $Ca(g) \longrightarrow Ca^{+}(g) + e$
(c) $Ca(s) \longrightarrow Ca^{+}(g) + e$ (d) $Ca(g) \longrightarrow Ca^{2+}(g) + 2e$

18. Which of the following oxides is neutral?

(a) SnO_2 (b) CO
(c) Al_2O_3 (d) Na_2O

19. Which of the following is the least stable?

(a) PbI_4 (b) KCl (c) GeI_4 (d) SnI_4

20. Among the following, the element with the lowest atomic number that has a ground-state electronic configuration of $(n-1)d^6ns^2$ is located in the

(a) fifth period (b) sixth period
(c) fourth period (d) third period

21. Which of the following properties does not depend on periodicity?

(a) Atomic weight (b) Atomic number
(c) Ionization energy (d) Electronegativity

22. The electronegativity of the following elements increases in the order

(a) $C < N < Si < P$ (b) $Si < P < C < N$
(c) $N < C < P < Si$ (d) $C < Si < N < P$

23. Which of the following is arranged in order of increasing radius?

(a) $K^{+}(aq) < Na^{+}(aq) < Li^{+}(aq)$
(b) $K^{+}(aq) > Na^{+}(aq) > Zn^{2+}(aq)$
(c) $K^{+}(aq) < Li^{+}(aq) < Na^{+}(aq)$
(d) $Li^{+}(aq) < Na^{+}(aq) < K^{+}(aq)$

24. The third ionization energy is maximum for

(a) nitrogen (b) phosphorus
(c) aluminium (d) boron

25. The correct order of increasing atomic radius of the following elements is

(a) $S < O < Se < C$ (b) $O < C < S < Se$
(c) $O < S < Se < C$ (d) $C < O < S < Se$

26. Which of the following arrangements shows the correct order of decreasing paramagnetism?

(a) $N > Al > O > Ca$ (b) $N > O > Al > Ca$
(c) $O > N > Al > Ca$ (d) $O > N > Ca > Al$

27. A large difference between the fourth and fifth ionization energies indicates the presence of

(a) 5 valence electrons in an atom
(b) 6 valence electrons in an atom
(c) 4 valence electrons in an atom
(d) 8 valence electrons in an atom

28. Which of the following has been arranged in order of increasing covalent character?

(a) $BaCl_2 < AlF_3 < BeCl_2 < LiCl$
(b) $KCl < NaCl < BeCl_2 < PbCl_4$
(c) $NH_4Cl < BCl_3 < CCl_4 < AlF_3$
(d) $KCl < CaCl_2 < AlCl_3 < SiCl_4$

29. Electron affinity is defined as the

(a) energy required to remove an electron from an isolated gaseous atom
(b) energy released when an electron is added to an isolated atom in the gaseous state
(c) energy required to add an electron to an isolated atom in the gaseous state
(d) ability of an atom to attract an electron

30. Which of the following halides is stable to hydrolysis?

(a) $SiCl_4$ (b) PF_3 (c) NCl_3 (d) NF_3

31. Which of the following is arranged in order of increasing thermal stability?

(a) $HgCl_2 < BeCl_2 < CaCl_2 < BaCO_3$
(b) $BaCl_2 < CaCl_2 < BeCl_2 < HgCl_2$
(c) $CaCl_2 < BeCl_2 < BaCO_3 < HgCl_2$
(d) $BeCl_2 < BaCl_2 < HgCl_2 < CaCl_2$

32. The correct order of increasing electron affinity of the following elements is

(a) $C < Be < N < O < F$ (b) $Be < C < O < N < F$
(c) $Be < C < N < O < F$ (d) $Be < C < N < F < O$

33. Which of the following has been arranged in order of the increasing stability of the +2 oxidation state of the ions?

(a) $Ca^{2+} < Ba^{2+} < Sr^{2+}$
(b) $Pb^{2+} < Ge^{2+} < Sn^{2+}$
(c) $Ge^{2+} < Sn^{2+} < Pb^{2+}$
(d) $Cu^{2+} < Au^{2+} < Ag^{2+}$

34. Which of the following is arranged in order of increasing density?

(a) Al < Mg < C (graphite) < B
(b) B < Al < Mg < C (graphite)
(c) C (graphite) < Al < B < Mg
(d) Mg < C (graphite) < B < Al

35. Which of the following represents the correct outer-shell electronic configuration of Group 13 elements?

(a) $ns^2\, nd^1$
(b) $ns^2\, np^6$
(c) $ns^2\, np^1$
(d) $ns^2\, np^3$

36. Among the following, which has the lowest enthalpy of fusion?

(a) Fluorine
(b) Hydrogen
(c) Chlorine
(d) Helium

37. Which of the following is arranged in order of increasing density?

(a) Ag < Au < Fe < Cu
(b) Cu < Au < Ag < Fe
(c) Fe < Cu < Ag < Au
(d) Au < Ag < Cu < Fe

38. What is the electronic configuration of the outer shell of the elements of Group 14?

(a) $ns^2\, np^4$ (b) $ns^2\, np^6$ (c) $ns^2\, np^2$ (d) ns^2

39. Which of the following is arranged in order of increasing boiling point?

(a) $H_2O < CCl_4 < CS_2 < CO_2$
(b) $CO_2 < CS_2 < CCl_4 < H_2O$
(c) $CS_2 < H_2O < CO_2 < CCl_4$
(d) $CCl_4 < H_2O < CO_2 < CS_2$

40. Which of the following is arranged in order of increasing density?

(a) $Ne < Cl_2 < N_2 < O_2$
(b) $N_2 < O_2 < Ne < Cl_2$
(c) $Cl_2 < Ne < O_2 < N_2$
(d) $Cl_2 < N_2 < O_2 < Ne$

41. Which of the following is arranged in decreasing order of size?

(a) $Mg^{2+} > Al^{3+} > O^{2-}$
(b) $O^{2-} > Mg^{2+} > Al^{3+}$
(c) $Al^{3+} > Mg^{2+} > O^{2-}$
(d) $Mg^{2+} \approx Al^{3+} > O^{2-}$

42. Which of the following compounds has a positive enthalpy of solution?

(a) LiF
(b) LiCl
(c) LiBr
(d) LiI

43. Which of the following is arranged in order of increasing second ionization energy?

(a) $C < N < O < F$ (b) $F < C < N < O$
(c) $C < N < F < O$ (d) $F < O < N < C$

44. The order of increasing ionic radius of the following is

(a) $K^+ < Li^+ < Mg^{2+} < Al^{3+}$
(b) $K^+ < Mg^{2+} < Li^+ < Al^{3+}$
(c) $Li^+ < K^+ < Mg^{2+} < Al^{3+}$
(d) $Al^{3+} < Li^+ < Mg^{2+} < K^+$

45. Which of the following compounds has a negative enthalpy of solution?

(a) KCl (b) KBr
(c) KF (d) KI

46. Which of the following statements is incorrect?

(a) The second ionization energy of sulphur is greater than that of chlorine.
(b) The third ionization energy of phosphorus is greater than that of aluminium.
(c) The first ionization energy of aluminium is approximately the same as that of gallium.
(d) The second ionization energy of boron is greater than that of carbon.

47. Which of the following electronic configurations corresponds to the element with the highest electron affinity?

(a) $[Ar]\,3d^{10}\,4s^2\,4p^3$ (b) $[Ar]\,3d^{10}\,4s^2\,4p^4$
(c) $[Ar]\,3d^{10}\,4s^2\,4p^5$ (d) $[Ar]\,3d^{10}\,4s^2\,4p^6$

48. The ionization energies of which of the following pairs of elements increase in a regular and integral manner?

(a) Nitrogen and phosphorus (b) Oxygen and fluorine
(c) Boron and aluminium (d) Sodium and magnesium

49. Among the following elements, the second ionization energy is maximum for

(a) boron (b) beryllium
(c) magnesium (d) aluminium

50. Arrange N, O and S in order of decreasing electron affinity.

(a) $S > O > N$ (b) $O > S > N$
(c) $N > O > S$ (d) $S > N > O$

51. Arrange the elements with the following electronic configurations in increasing order of electron affinity.

(i) $1s^2 2s^2 2p^5$ (ii) $1s^2 2s^2 2p^4$

(iii) $1s^2 2s^2 2p^3$ (iv) $1s^2 2s^2 2p^6 3s^2 3p^4$

(a) i < ii < iii < iv (b) iv < iii < ii < i

(c) iii < ii < iv < i (d) ii < iii < i < iv

52. Which of the following pairs of compounds has positive enthalpies of solution?

(a) NaF and NaCl (b) NaBr and NaI

(c) NH_4Cl and NH_4F (d) CaF_2 and $CaCl_2$

53. Among the following elements, which has the least electron affinity?

(a) Phosphorus (b) Sulphur

(c) Oxygen (d) Nitrogen

54. The basicity of the hydroxides of the following alkali metals is of the order

(a) Li > Na > Rb > Cs (b) Na > Li > Rb > Cs

(c) Cs > Rb > Na > Li (d) Rb > Cs > Na > Li

55. The basic strengths of the hydroxides of the following alkaline earth metals follow the order

(a) Be > Mg > Sr > Ba (b) Mg > Be > Ba > Sr

(c) Ba > Sr > Mg > Be (d) Sr > Be > Mg > Ba

56. The solubilities of Na_2SO_4, $BeSO_4$, $MgSO_4$ and $BaSO_4$ follow the order

(a) $BeSO_4 > MgSO_4 > Na_2SO_4 > BaSO_4$

(b) $Na_2SO_4 > BeSO_4 > MgSO_4 > BaSO_4$

(c) $BeSO_4 > Na_2SO_4 > MgSO_4 > BaSO_4$

(d) $MgSO_4 > BeSO_4 > Na_2SO_4 > BaSO_4$

57. The basic character of MgO, SrO, K_2O and NiO increases in the order

(a) K_2O < SrO < MgO < NiO (b) NiO < MgO < SrO < K_2O

(c) MgO < NiO < SrO < K_2O (d) K_2O < MgO < NiO < SrO

58. Which of the following is arranged in order of increasing electron affinity?

(a) C < O < N < B (b) N < O < B < C

(c) O < C < B < N (d) N < B < C < O

59. Which of the following statements is correct?

(a) The magnitude of the second electron affinity of sulphur is greater than that of oxygen.

(b) The magnitude of the second electron affinity of sulphur is less than that of oxygen.

(c) The first electron affinities of bromine and iodine are approximately the same.

(d) The first electron affinity of fluorine is greater than that of chlorine.

60. Which of the following pairs of molecules have the identical bond dissociation energies?

(a) F_2 and H_2 (b) N_2 and CO

(c) F_2 and I_2 (d) HF and O_2

61. Which of the following arrangements is correct in terms of electron affinity?

(a) Chlorine > fluorine > iodine > bromine

(b) Bromine < iodine < chlorine < fluorine

(c) Bromine < iodine < fluorine < chlorine

(d) Bromine ≈ iodine > chlorine < fluorine

62. Among the following oxides, which has the maximum lattice energy?

(a) MgO (b) CaO

(c) SrO (d) BaO

63. Among the following molecules, which has the maximum lattice energy?

(a) KBr (b) NaCl

(c) NaF (d) LiF

64. Which of the following is arranged in increasing order of hydration energy?

(a) $Cu^{2+} < Fe^{3+} < Fe^{2+} < Al^{3+}$

(b) $Fe^{2+} < Cu^{2+} < Al^{3+} < Fe^{3+}$

(c) $Al^{3+} < Fe^{3+} < Fe^{2+} < Cu^{2+}$

(d) $Fe^{3+} < Al^{3+} < Cu^{2+} < Fe^{2+}$

65. Among the following, which has the maximum hydration energy?

(a) OH^- (b) NH_4^+ (c) F^- (d) H^+

66. Which of the following is arranged in order of increasing melting point?

(a) Zn < Cu < Ni < Fe (b) Fe < Ni < Cu < Zn

(c) Ni < Fe < Zn < Cu (d) Cu < Zn < Fe < Ni

67. Which of the following is arranged in order of decreasing melting point?

(a) S > P > Si > Al (b) Al > Si > P > S

(c) Si > Al > S > P (d) P > S > Al > Si

68. Among the following, which has the maximum density?
(a) Sulphur (b) Phosphorus (c) Silicon (d) Aluminium

69. Which of the following is arranged in order of decreasing boiling point?
(a) Mg > Ca > Hg > Zn (b) Hg > Zn > Mg > Ca
(c) Ca > Mg > Zn > Hg (d) Zn > Hg > Ca > Mg

70. Which of the following pairs includes elements with almost the same covalent radii?
(a) Hydrogen and helium (b) Iodine and bromine
(c) Nitrogen and oxygen (d) Sulphur and chlorine

71. Among the following metals, the most dense is
(a) osmium (b) iridium (c) platinum (d) gold

72. Which of the following sets has elements with identical covalent radii?
(a) B, C, N, O (b) Al, Si, P, S
(c) Cr, Mn, Fe, Cu (d) Li, Be, B, C

73. Among the following, the third ionization energy is maximum for
(a) aluminium (b) boron
(c) magnesium (d) beryllium

• Type 2 •

Choose the correct options. More than one option is correct.

74. Paramagnetism is exhibited by elements, the atoms of which have
(a) only an odd number of electrons
(b) only an even number of electrons
(c) the d-shell partially filled
(d) none of these

75. In halogens, which of the following increases from iodine to fluorine?
(a) Bond length
(b) Electronegativity
(c) The ionization energy of the element
(d) Oxidizing power

76. Which of the following have isoelectronic structures?
(i) CH_3^+ (ii) H_3O^+ (iii) CH_3^- (iv) NH_3
(a) (i) and (ii) (b) (i) and (iii)
(c) (iii) and (iv) (d) (ii), (iii) and (iv)

77. Which among the following are isostructural pairs?

(a) NF_3 and H_3O^+ (b) NO_3^- and BF_3

(c) NF_3 and NO_3^- (b) NF_3 and NH_3

78. Which of the following statements are correct?

(a) F is the most electronegative and Cs the most electropositive element.

(b) The electronegativity of halogens decreases from F to I.

(c) The electron affinity of Cl is higher than that of F though their electronegativities are in the reverse order.

(d) The electron affinity of noble gases is almost zero.

79. Which of the following statements are true?

(a) Mendeleev's periodic law is based on the atomic numbers of elements.

(b) The table presented by Mendeleev did not have the zero group.

(c) Each group in Mendeleev's periodic table was divided into two subgroups.

(d) Mendeleev's periodic table consists of ten horizontal rows or series.

80. Which of the following have a diagonal relationship?

(a) Li and Mg (b) B and Mg

(c) Be and Al (d) Be and Na

81. Which of the following belong to a triad?

(a) Osmium (b) Platinum

(c) Iridium (d) Palladium

82. Which of the following are correct?

(a) The configuration of M o$(Z = 42)$ is [Kr] $4d^5\,5s^1$.

(b) The configuration of Pd$(Z = 46)$ is [Kr] $4d^8\,5s^2$.

(c) The configuration of Pd$(Z = 46)$ is [Kr] $4d^{10}\,5s^0$.

(d) The configuration of Pt$(Z = 78)$ is [Xe] $4d^9\,6s^1$.

83. Which of the following elements are present in group 16 of the periodic table?

(a) Sulphur (b) Arsenic

(c) Tellurium (d) Silicon

84. Which of the following species are isoelectronic with Ne?

(a) N^{3-} (b) Mg^{2+}

(c) Al^{3+} (d) Ca^{2+}

85. In which of the following are the orders of electron affinity of the elements or ions shown correctly?

(a) $S > O^-$ (b) $O > S^-$

(c) $O^- > S^-$ (d) $N^- > P$

86. Which of the following salts does not undergo hydrolysis?

(a) NaCl (b) KCN

(c) $KClO_4$ (d) Na_2CO_3

87. Which of the following statements are correct?

(a) Liquid oxygen sticks to the poles of magnet.

(b) Silver perchlorate is soluble in water.

(c) The atomic size of silver is less than that of gold.

(d) Many peroxides are coloured because of the presence of superoxides.

88. Which of the following halides are soluble in water?

(a) AlF_3 (b) AgI

(c) AgCl (d) AgF

89. Which of the following pairs have approximately the same atomic radii?

(a) Pd and Pt (b) Al and Mg

(c) Al and Ga (d) Na and Ne

90. Diagonal relationships are shown by

(a) Be and Al (b) Li and Mg

(c) Mg and Al (d) B and P

91. The ionic bonds X^+Y^- are formed when the

(a) electron affinity of Y is high

(b) ionization energy of X is low

(c) lattice energy of XY is high

(d) lattice energy of XY is low

92. Which of the folloiwng statements are correct?

(a) The melting point of boron is greater than that of carbon.

(b) The melting point of boron is less than that of carbon.

(c) BF_3 is a weaker electron acceptor than BBr_3.

(d) *trans*-1,2-Dichloro-2-pentene has a dipole moment.

93. Which of the following species are not known?

(a) AgOH (b) SH_6

(c) PbI_4 (d) PI_5

94. Which of the following pairs has elements that do not belong to the same period?

(a) Mg and Sb (b) Ca and Zn
(c) Na and Ca (d) Ca and Cl

95. Which of the following pairs do not show the inert-pair effect?

(a) Cu and Au (b) Si and Ge
(c) Tl and Pb (d) Bi and Sn

Answers

1. b	**2.** d	**3.** d	**4.** b	**5.** a
6. d	**7.** d	**8.** b	**9.** b	**10.** c
11. d	**12.** d	**13.** c	**14.** d	**15.** c
16. c	**17.** b	**18.** b	**19.** a	**20.** c
21. a	**22.** b	**23.** a	**24.** a	**25.** b
26. b	**27.** c	**28.** d	**29.** b	**30.** d
31. a	**32.** c	**33.** c	**34.** d	**35.** c
36. d	**37.** c	**38.** c	**39.** b	**40.** b
41. b	**42.** a	**43.** c	**44.** d	**45.** c
46. a	**47.** c	**48.** a	**49.** a	**50.** a
51. c	**52.** c	**53.** d	**54.** c	**55.** c
56. b	**57.** b	**58.** d	**59.** b	**60.** c
61. c	**62.** a	**63.** d	**64.** b	**65.** d
66. a	**67.** c	**68.** d	**69.** c	**70.** c
71. b	**72.** c	**73.** b	**74.** a, c	**75.** b, c, d
76. c, d	**77.** a, b	**78.** a, b, c, d	**79.** b, c	**80.** a, c
81. a, b, c	**82.** a, c, d	**83.** a, c	**84.** a, c	**85.** a, b
86. a, c	**87.** a, b, d	**88.** a, d	**89.** a, c	**90.** a, b
91. a, b	**92.** b, c	**93.** a, b, c, d	**94.** a, c, d	**95.** a, b

Hints to More Difficult Problems

1. The effective nuclear charge is the largest for sodium and the least for phosphorus.

2. These are transition metals with the $(n-1)d^{1-10}ns^{1-2}$ configuration, which is associated with transition contraction.

4. Apply Fajans' rules.

8. Van der Waals forces

12. Greatest size, and hence lowest value of ionization energy

14. Lattice energy considerations

19. PbI_4 disproportionates easily: $PbI_4 \rightarrow PbI_2 + I_2$.

22. The smaller the size, the greater is the electronegativity

23. The reason for this apparent anomaly is that the ions are hydrated in solution. Since Li^+ is very small, it is heavily hydrated. This makes the radius of the hydrated ion large. In contrast K^+ (aq.) is the least hydrated because it is the largest.

28. Apply Fajans' rules.

30. The electronegative fluorines in NF_3 balance the electron distribution around N to such an extent that the dipole moment is only 0.2 D.

31. The size of the cations, and lattice energy considerations

33. Inert-pair effect

37. Close-packed structures

39. Hydrogen-bonding in water, and molar mass for the rest of the molecules

43. The size of the elements and electronic configuration

54. Greater size and lower ionization energy

56. Lattice-energy considerations

60. The low dissociation energy of F_2 arises from the repulsion between the unpaired electrons on the two atoms which are themselves small

61. Electron-electron interaction and effect of p-orbital repulsion

63. Lattice energy $U^- \propto Z_+ Z_-$

$$\propto \frac{1}{r}$$

64. The smaller the size, the greater is the lattice energy.

68. Al has the most packed structure.

69. Hg has the weakest metallic bond, and Ca the strongest.

73. Stable electronic configuration

77. Both have pyramidal structures

80. On moving across a period, the charge on the ions increases and the size decreases, causing the polarizing power to increase. On moving down a Group, the size increases and the polarizing power decreases. On moving diagonally these two effects partly cancel each other. So there is no marked change in properties.

85. Energy is evolved when 1 electron is added to an O or S atom forming O^- and S^- ions, but a substantial amount of energy is absorbed when 2 electrons are added to these atoms to form O^{2-} and S^{2-} ions.

93. Weak bond strength and coordination unsaturation

95. The inert-pair effect is shown by elements of groups 13, 14, 15 and 16, which have elements of electronic configuration ns^2np^1, ns^2np^2, ns^2np^3 and ns^2np^4 respectively.

❑

2

Hydrogen and Oxygen

• *Type 1* •

Choose the correct option. Only one option is correct.

1. The hydrogen molecule is not very reactive under normal conditions because

(a) hydrogen has a large number of isotopes

(b) the corresponding $\Delta S°$ value is very low

(c) the bond dissociation energy of the hydrogen molecule is high

(d) the hydrogen molecule has a low activation energy

2. The ionization constant of protium in water $(H_2O \rightleftharpoons H^+ + OH^-)$ is 1.0×10^{-14} and that in heavy water $(D_2O \rightleftharpoons D^+ + OD^-)$ is $3{\cdot}0 \times 10^{-15}$. H_2O dissociates about

(a) three times as much as D_2O does.

(b) thirty times as much as D_2O does.

(c) 0.3 times as much as D_2O does.

(d) 300 times as much as D_2O does.

3. The order of the heats of fusion of T_2, D_2 and H_2 is

(a) $T_2 > D_2 > H_2$ (b) $H_2 > T_2 > D_2$

(c) $D_2 > T_2 > H_2$ (d) $D_2 = T_2 > H_2$

4. The higher density of water than that of ice is due to

(a) dipole-dipole interaction

(b) dipole–induced dipole interaction

(c) hydrogen bonding

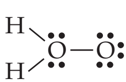
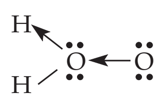
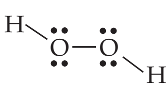
(d) all of these

5. In parahydrogen, the electron spins are in the
(a) same direction but the proton spins are in opposite directions
(b) opposite directions but the proton spins are in the same direction
(c) same direction as the proton spins
(d) opposite direction to the proton spins

6. Among the following, the latent heats of fusion and vaporization are maximum in
(a) H_2 (b) D_2 (c) T_2 (d) H_2^+

7. A dilute solution of H_2O_2 can be concentrated by
(a) drying it over anhydrous $CaCl_2$
(b) drying it over concentrated H_2SO_4
(c) drying it over anhydrous $MgSO_4$
(d) heating it under reduced pressure

8. Which of the following mixtures is known as the Fenton reagent?
(a) $TiCl_4$ and $Al(C_2H_5)_3$ (b) $FeSO_4$ and H_2O_2
(c) $FeCl_3$ and H_2O_2 (d) CH_3COONH_4 and H_2O_2

9. Which of the following is the true structure of H_2O_2?
(a) 
(b) 
(c) 
(d) H—O=O—H

10. Hydrogen gas is generally prepared by the
(a) reaction of granulated zinc with dilute H_2SO_4
(b) reaction of zinc with concentrated H_2SO_4
(c) reaction of pure zinc with dilute H_2SO_4
(d) action of steam on red-hot coke

11. Superoxides are
(a) stronger oxidizing agents than peroxides
(b) weaker oxidizing agents than peroxides
(c) weaker reducing agents than oxygen
(d) stronger reducing agents than H_2O_2

12. Which of the following statements is correct? NaO_2 has a
(a) graphite-like structure.
(b) rock-salt (NaCl)-like structure.

(c) pyrite (FeS_2)-like structure.

(d) fluorite (CaF_2)-like structure.

13. Ortho- and parahydrogen differ in

(a) atomic number (b) mass number

(c) nuclear spin (d) all of these

14. In ozone, the central oxygen atom uses

(a) roughly sp^2 orbitals for σ-bonding

(b) sp orbitals for π-bonding

(c) sp^3 orbitals for σ-bonding

(d) pd_z^2 orbitals for σ- and π-bonding

15. The structure of ozone involves

(a) delocalized three-centre σ-bonding

(b) delocalized three-centre π-bonding

(c) delocalized three-centre σ- as well as π-bonding

(d) localized π-bonding

16. The pale blue colour of ozone gas is due to the intense absorption of

(a) infrared radiation (b) cosmic radiation

(c) red light (d) blue light

17. Ozone is a powerful oxidizing agent. It is

(a) less oxidizing than F_2 (b) more oxidizing than F_2

(c) less oxidizing than O_2 (d) less oxidizing than H_2O_2

18. Ozone oxidizes PbS to

(a) PbO_2 (b) Pb_3O_4

(c) PbO (d) $PbSO_4$

19. Ozone reacts with a KOH solution to produce

(a) O_2 and K_2O (b) O_2 and K_2O_2

(c) O_2 only (d) KO_3

20. The volume of oxygen obtained by the decomposition of 4 L of O_3 at stp is

(a) 3 L (b) 9 L

(c) 6 L (d) 2 L

21. Ozone is

(a) an allotrope of oxygen (b) an isomer of oxygen

(c) an isotone of oxygen (d) isostructural with H_2O_2

22. Which of the following compounds produces holes in the ozone layer in the upper atmosphere?

(a) Sulphur dioxide (b) Carbon dioxide

(c) Freon (d) Carbon monoxide

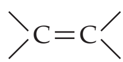
23. Which of the following statements is correct?

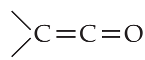
(a) The ionization energy of hydrogen is the same as the first ionization energy of helium.

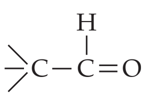
(b) The electronegativity of hydrogen is the same as that of carbon.

(c) Hydrogen gas is liberated at the anode during the electrolysis of molten lithium hydride.

(d) Hydrogen gas is liberated at the cathode during the electrolysis of molten lithium hydride.

24. The ozonolysis of  produces

(a)  (b) 

(c)  (d) 

25. Ozone can be detected by using

(a) Na (b) Ag

(c) Hg (d) Ar

26. A pale blue gas with a fish-like odour restores the colour of a blackened lead painting. The gas is also used as a rocket fuel. It is

(a) O_2 (b) NH_3

(c) SO_2 (d) O_3

27. Water undergoes self-ionization to a small extent to give

(a) H^+ and OH^- (b) OH^+ and H^-

(c) H_3O^+ and OH^- (d) $H_3O_2^+$ and OH^-

28. In which of the following compounds does deuteration take place easily on treatment with D_2O?

(a) CH_3CH_2OH (b) CH_3—CH_3

(c) CH_3CH_2—O—CH_2CH_3 (d) CH_3CH_2Cl

29. Which of the following pairs have an almost identical geometry?

(a) H_3O^+ and AlF_3 (b) NH_3 and H_3O^+

(c) H_2O and ICl_2^- (d) H_2O and NO_2^+

30. Which of the following compounds has not yet been prepared?

(a) D_2S (b) T_2S

(c) D_2O (d) H_2Po

31. Which of the following nuclear reactions is used to prepare tritium?

(a) ${}^{8}_{4}Be + {}^{2}_{4}He \longrightarrow {}^{3}_{1}H + {}^{9}_{5}B$ (b) ${}^{2}_{1}D + {}^{2}_{1}D \longrightarrow {}^{3}_{1}H + {}^{1}_{1}H$

(c) ${}^{7}_{3}Li + {}^{1}_{0}n \longrightarrow {}^{3}_{1}H + {}^{4}_{2}He$ (d) ${}^{10}_{5}B + {}^{1}_{0}n \longrightarrow 2\,{}^{4}_{2}He + {}^{3}_{1}H$

32. Acetone exhibits keto-enol tautomerism:

$$(CH_3)_2C{=}O \rightleftharpoons CH_3-\overset{\displaystyle OH}{\overset{|}{C}}{=}CH_2$$

Which of the following products is obtained when acetone is treated with an excess of D_2O for a sufficient time in the presence of a small amount of a dilute NaOH solution?

(a) $CH_3-\overset{\displaystyle OD}{\overset{|}{C}}{=}CH_2$ (b) $CH_2D-\overset{\displaystyle OH}{\overset{|}{C}}{=}CH_2$

(c) $CD_3-\overset{\displaystyle O}{\overset{\|}{C}}-CD_3$ (d) $CH_3-\overset{\displaystyle OD}{\overset{|}{C}}{=}CHD$

33. Which of the following is incorrect?

(a) $NH_4^+ + D_2O \rightleftharpoons NH_3D^+ + HDO$

(b) $PH_3 + D_2O \rightleftharpoons PD_3 + H_2O$

(c) $CH_3NH_2 + D_2O \rightleftharpoons CH_3NHD + HDO$

(d) $CH_3OH + D_2O \rightleftharpoons CH_3OD + HDO$

34. Most covalent compounds have a very low solubility in water because of the

(a) low hydration energy due to the weak interaction between the polar water molecules and the nonpolar covalent molecules, which is insufficient to break the hydrogen bonds between the water molecules

(b) low dielectric constant of water

(c) high dipole moment of water

(d) high density of water

35. Zeolite is

(a) hydrated sodium aluminium silicate—$Na_2Al_2Si_2O_8{\cdot}xH_2O$

(b) hydrated ferric oxide

(c) sodium hexametaphosphate

(d) sodium tetraborate

36. Hard water is not suitable for washing clothes because
(a) it contains Na_2SO_4 and KCl
(b) it hydrolyses soap
(c) it gives a precipitate with soap
(d) water forms micelles with soap

37. The degree of hardness of water is usually expressed in terms of
(a) parts per million by weight of $MgSO_4$
(b) grams per litre of $CaCO_3$ and $MgCO_3$ actually present
(c) parts per million by weight of $CaCO_3$ regardless of whether it is actually present
(d) parts per million of $CaCO_3$ actually present in water

38. Hydrogen is obtained as a by-product in the
(a) electrolysis of water
(b) manufacture of caustic soda
(c) Bosch process
(d) Lane process

39. Calgon, which is used as a water softener, has the formula
(a) $Na_4[Na_2(PO_3)_6]$ (b) $Na_2[Na_4(PO_3)_6]$
(c) $Na_2[Na_4(PO_4)_5]$ (d) $Na_2[Na_2(PO_4)_6]$

40. Heavy water freezes at
(a) 270.7 K (b) 276.1 K
(c) 269.2 K (d) 276.8 K

41. Heavy water is usually prepared by the
(a) reaction of D_2 with $NH_4^+ OH^-$
(b) oxidation of D_2 with ozone
(c) prolonged multistage electrolysis of a 0.5 M NaOH solution using nickel electrodes
(d) prolonged electrolysis of the solution of a mixture of $Ba(OH)_2$ and H_2SO_4

• *Type 2* •

Choose the correct options. More than one option is correct.

42. Water may be softened using
(a) sodium aluminium silicate (b) Graham's salt
(c) an ion-exchange resin (d) trisodium phosphate

43. The presence of water can be inferred by
(a) using anhydrous $CuSO_4$ which changes colour
(b) using anhydrous $CoCl_2$ which changes colour from blue to pink
(c) the use of hydrated $CuSO_4$
(d) smell

44. Hydrogen peroxide is used as
(a) a reducing agent
(b) an oxidant of rocket fuel
(c) an oxidizing agent
(d) a bleaching agent

45. Which of the following statements are correct?
(a) Hydrogen, like alkali metals, is electropositive.
(b) Like alkali metals, hydrogen shows an oxidation state of +1 in its compounds.
(c) Like alkali metals, hydrogen acts as a strong reducing agent.
(d) Hydrogen shows an oxidation state of –1 in covalent hydrides.

46. Which of the following statements are correct?
(a) Like halogens, hydrogen combines with nonmetals to form covalent compounds.
(b) Hydrogen as well as halogens have a tendency to accept electrons.
(c) The oxide of hydrogen is neutral, as is the case with the oxides of halogens, e.g., Cl_2O_7.
(d) Hydrogen and halogens form hydride ions with equal ease.

47. In which of the following does hydrogen exist in a negative oxidation state?
(a) HCl
(b) CaH_2
(c) B_2H_6
(d) $Li[AlH_4]$

48. Which of the following statements are correct?
(a) Water is amphoteric.
(b) Water acts as an oxidizing agent.
(c) Water acts as a reducing agent.
(d) Sodium hydride is insoluble in water.

49. The decomposition of H_2O_2 is retarded by
(a) acetanilide
(b) glycerol
(c) sodium bicarbonate
(d) oxalic acid

50. Which of the following statements are correct?
(a) Dihydrogen is neutral to litmus.
(b) Dihydrogen dissociates into hydrogen atoms only on being heated to above 2000 K.

(c) The reactivity of hydrogen towards halogens decreases in the order $Cl > Br > I > F$.

(d) Dihydrogen can reduce CuO and ZnO to their metals.

51. Which of the following metals form saline hydrides?

(a) Li (b) Be

(c) Na (d) Mg

52. Which of the following statements are correct?

(a) At 0 K, hydrogen gas contains 100% parahydrogen.

(b) At high temperature, hydrogen contains about 75% orthohydrogen.

(c) Parahydrogen has lower energy than orthohydrogen.

(d) At high temperature, hydrogen contains about 75% parahydrogen.

53. Which of the following statements are correct in the context of peroxide ions?

(a) They are oxidizing agents.

(b) They are salts of a weak diprotic acid (H_2O_2).

(c) They react with acids to give H_2O_2.

(d) The bond order of the O_2^{2-} ion is 1.5.

54. Which of the following statements are correct?

(a) Peroxide and superoxide ions are larger than oxide ions.

(b) The stability of peroxides and superoxides increases as the metal ions become larger.

(c) The bond order of superoxides is 1.5.

(d) Many peroxides are coloured due to the presence of a superoxide.

55. Which of the following statements are correct?

(a) H_2O_2 is a pale blue viscous liquid.

(b) H_2O_2 can act as an oxidizing as well as a reducing agent.

(c) In H_2O_2 the two hydroxyl groups lie on the same plane.

(d) H_2O_2 has an 'open-book' structure.

56. 10-volume H_2O_2 is equivalent to

(a) 10% (b) 3% H_2O_2 (W/V)

(c) 30 g/L (d) 1.786 N

57. On treatment of hard water with zeolite, sodium ions get exchanged with

(a) Ca^{2+} ions (b) H^+ ions

(c) Mg^{2+} ions (d) OH^-

58. Which of the following statements are correct?
   (a) There is a layer of ozone in the upper atmosphere which absorbs harmful UV radiation from the sun, thus protecting life on earth.
   (b) Freons produce holes in the upper atmosphere.
   (c) Oxides of nitrogen and halogens can damage the ozone layer.
   (d) Ozone is prepared by the action of a silent electric discharge upon an oxygen molecule.

Answers

1. c	**2.** a	**3.** a	**4.** c	**5.** d
6. c	**7.** d	**8.** b	**9.** c	**10.** a
11. a	**12.** a	**13.** c	**14.** a	**15.** b
16. c	**17.** a	**18.** d	**19.** d	**20.** c
21. a	**22.** c	**23.** c	**24.** a	**25.** c
26. d	**27.** c	**28.** a	**29.** b	**30.** b
31. b	**32.** c	**33.** b	**34.** a	**35.** a
36. c	**37.** c	**38.** b	**39.** b	**40.** d
41. c	**42.** b, c, d	**43.** a, b	**44.** a, b, c, d	**45.** a, b, c
46. a, b	**47.** b, d	**48.** a, b, c	**49.** a, b	**50.** a, b, d
51. a, c	**52.** a, b, c	**53.** a, b, c	**54.** a, b, c, d	**55.** a, b, d
56. b, c, d	**57.** a, c	**58.** a, b, c, d		

Hints to More Difficult Problems

3. Decreasing atomic mass

11. Higher reduction potential

17. $E^0_{O_3/O^{2-}} = +2.07$ V

24. O_3 attacks the C=C double bond.

26. Exothermicity

28. The more polar CH_3CH_2OH causes D_2O to react or exchange.

31. Apply the minimum-energy concept.

33. PH_3 does not contain labile hydrogen. The electronegativity values of P and H are nearly the same.

38. $4OH^- \longrightarrow 2H_2O + O_2 + 4e$

40. From the partial phase diagram of water

47. (b) and (d) are metal hydrides.

48. $2H_2O + 2e \longrightarrow 2OH^- + H_2$ (H_2O is an oxidizing agent)

$2H_2O \longrightarrow 4H^+ + O_2 + 4e$ (H_2O is a reducing agent)

$$\underset{}{H_2O} \rightleftharpoons \underset{10^{-7}\ \text{mol/L}}{H^+} + \underset{10^{-7}\ \text{mol/L}}{OH^-}$$ (H_2O is amphoteric)

49. Acetanilide and glycerol are negative catalysts.

51. Li and Na form ionic hydrides.

56. $$\underset{68\ \text{g}}{2H_2O_2} \longrightarrow 2H_2O + \underset{22400\ \text{mL at stp}}{O_2}$$

10-vol. H_2O_2 means that 1 vol. of $H_2O_2 \equiv 10$ vol. of O_2 at stp

or 1 mL of $H_2O_2 \equiv 10$ mL of O_2 at stp

22400 mL of O_2 at stp = 68 g of H_2O_2

10 mL of O_2 at stp = 3×10^{-2} g of H_2O_2

Thus 1 mL of H_2O_2 soln = 3×10^{-2} of H_2O_2

100 mL of H_2O_2 soln = 3g of H_2O, i.e. 3% W/V

❑

3

Alkali Metals and Alkaline Earth Metals

• *Type 1* •

Choose the correct option. Only one option is correct.

1. The magnitude of enthalpy of formation of alkali metal halides decreases in the order

(a) iodide > bromide > chloride > fluoride
(b) bromide > iodide > fluoride > chloride
(c) fluoride > chloride > bromide > iodide
(d) fluoride > chloride > iodide > bromide

2. Alkali metals react with hydrogen forming ionic hydrates. The reactivity of the alkali metals with hydrogen decreases in the order

(a) Li > Na > K > Rb > Cs   (b) Na > K > Rb > Cs > Li
(c) Rb > Cs > Li > Na > K   (d) Cs > Rb > K > Na > Li

3. Which of the following reacts with nitrogen to form a nitride which finally hydrolyses to ammonia?

(a) K   (b) Li
(c) Na   (d) Cs

3. Which of the following pairs cannot exist together in solution?

(a) Na_2CO_3 and NaOH   (b) Na_2CO_3 and $NaHCO_3$
(c) $NaHCO_3$ and NaOH   (d) $NaHCO_3$ and NaCl

5. Among the following, which has the least ionic mobility?

(a) Na^+ (b) K^+ (c) Li^+ (d) Cs^+

6. The lattice energies of the oxides of Mg, Ca, Sr and Ba follow the order

(a) BaO > SrO > CaO > MgO   (b) CaO > BaO > SrO > MgO
(c) MgO > SrO > CaO > BaO   (d) MgO > CaO > SrO > BaO

7. When an alkali metal is introduced into a flame, it imparts a distinctive colour to it. The colour arises from

(a) electronic transitions in species formed momentarily in the flame

(b) the electronic transition $3s^1 \longrightarrow 3p^1$

(c) proton–proton transition

(d) d–d transition

8. Which of the following is used in photoelectric cells?

(a) Na (b) K

(c) Li (d) Cs

9. When heated to 800°C, $NaNO_3$ gives

(a) $NaNO_2 + O_2$ (b) $Na_2O + O_2 + N_2$

(c) $Na + N_2 + O_2$ (d) $NaN_3 + O_2$

10. A solution of sodium metal in liquid ammonia is blue, and is a strong reducing agent, due to the presence of

(a) sodium atoms

(b) sodium hydride

(c) sodium amide

(d) solvated electrons and solvated metal ions

11. The metallic lustre of sodium is explained by its

(a) fcc lattice structure

(b) the effusion of sodium ions

(c) the oscillation of its mobile valence electrons

(d) the band theory of metals

12. Which of the following forms the least ionic chloride?

(a) Be (c) Ca

(c) Mg (d) Sr

13. Lithium shows a diagonal relationship with

(a) sodium (b) silicon

(c) nitrogen (d) magnesium

14. Sodium thiosulphate may be prepared by any of the following reactions. Which of them is called Spring's reaction?

(a) $Na_2SO_3 + S \longrightarrow Na_2S_2O_3$

(b) $Na_2S + I_2 + Na_2SO_3 \longrightarrow Na_2S_2O_3 + 2NaI$

(c) $2Na_2S + Na_2CO_3 + 4SO_2 \longrightarrow 3Na_2S_2O_3 + CO_2$

(d) $S + 6NaOH \longrightarrow Na_2S_2O_3 + 2Na_2S + 3H_2O$

15. Which of the following statements is correct?
   (a) Sodium reacts with liquid ammonia to give hydrogen.
   (b) Sodamide is decomposed by water, producing ammonia.
   (c) Sodamide is decomposed by water, producing nitrogen.
   (d) Sodamide is used as a reducing as well as a dehydrating agent.

16. Lithium differs from alkali metals due to
   (a) the low hydration energy of Li^+
   (b) its b.c.c. structure
   (c) its extremely high electropositivity
   (d) its small atomic and ionic size

17. Sodium thiosulphate is used in photography to
   (a) convert metallic silver to a silver salt
   (b) reduce silver bromide to a silver salt
   (c) remove unreduced silver
   (d) remove undecomposed AgBr as a soluble silver thiosulphate complex

18. Sodium carbonate reacts with SO_2 in an aqueous medium to give
   (a) $NaHSO_3$ (b) $NaHSO_4$ (c) Na_2SO_3 (d) Na_2SO_4

19. In a nuclear reactor, molten sodium is used to
   (a) absorb neutrons for controlling the chain reaction
   (b) absorb the heat generated by a nuclear reaction
   (c) slow down fast neutrons
   (d) extract the radioisotopes produced in the reactor

20. When hydrated magnesium chloride ($MgCl_2 \cdot 6H_2O$) is heated,
   (a) MgO is formed
   (b) anhydrous $MgCl_2$ is formed
   (c) Mg(OH)HCl is formed
   (d) Mg(OH)Cl is formed

21. Anhydrous magnesium chloride can be prepared by heating $MgCl_2.6H_2O$
   (a) with concentrated HCl
   (b) in an atmosphere of nitrogen
   (c) in a current of dry HCl gas
   (d) in an atmosphere of hydrogen

22. In the Solvay process
   (a) an ammoniacal brine solution is carbonated with CO_2, forming $NaHCO_3$ which on decomposition at 150°C produces Na_2CO_3

(b) a sodium amalgam reacts with water to produce NaOH which gives Na_2CO_3 on reacting with CO_2

(c) a brine solution is made to react with $BaCO_3$ to produce Na_2CO_3

(d) brine is carbonated with CO_2 forming $NaHCO_3$ which on decomposition at 150°C produces Na_2CO_3

23. When a saturated solution of magnesium sulphate is treated with NH_4Cl and NH_3, followed by the addition of disodium hydrogen phosphate, a white precipitate of

(a) $Mg_2P_2O_7$ (b) $Mg_3(PO_4)_2$

(c) $Mg(NH_4)PO_4$ (d) $Mg(NH_4)HPO_4$

is formed.

24. The order of the solubility of the sulphates of alkaline earth metals in water is

(a) Be > Mg > Ca > Sr > Ba (b) Mg > Be >> Ba > Ca > Sr

(c) Be > Ca > Mg > Ba >> Sr (d) Mg > Ca > Ba >> Be > Sr

25. The solubility of the fluorides and hydroxides of alkaline earth metals increases on descending the group because the

(a) lattice energy of the compounds increases more rapidly than the hydration energy

(b) lattice energy of the compounds decreases more rapidly than the hydration energy

(c) size of the metals decreases on descending the group

(d) ionization energy of the metals increases on descending the group

26. On descending Group 2, the ions of the corresponding metals become larger. Therefore, the

(a) lattice energy and the hydration energy of the compounds decrease

(b) lattice energy of the compounds decreases and the hydration energy of the compounds encreases

(c) lattice energy and the hydration energy of the compounds increase

(d) lattice energy of the compounds increases and the hydration energy of the compounds decreases

27. Which of the following is the least thermally stable?

(a) $MgCO_3$ (b) $CaCO_3$

(c) $SrCO_3$ (d) $BeCO_3$

28. Magnesium is obtained by the electrolysis of fused magnesium chloride with sodium chloride. Sodium chloride helps

(a) lower the conductivity of $MgCl_2$

(b) raise the conductivity of $MgCl_2$
(c) lower the melting point of $MgCl_2$
(d) change the solid-state structure of $MgCl_2$

29. Magnesium is obtained by the electrolysis of fused magnesium chloride using
(a) a nickel cathode and a graphite anode
(b) a nickel container as cathode and an iron anode
(c) an iron container as cathode and a graphite anode
(d) a lead cathode and a platinum anode

30. The reducing property of alkali metals follows the order
(a) Na < K < Rb < Cs < Li (b) K < Na < Rb < Cs < Li
(c) Li < Cs < Rb < K < Na (d) Rb < Cs < K < Na < Li

31. An aqueous solution of magnesium sulphate and sodium carbonate gives
(a) $MgCO_3$ (b) $MgCO_3.Mg(OH)_2$
(c) $Mg(OH)_2$ (d) $Mg(HCO_3)_2$

32. An aqueous solution of magnesium sulphate and sodium bicarbonate gives
(a) $MgSO_4.Mg(OH)_2$ (b) $MgCO_3.Mg(OH)_2$
(c) $Mg(OH)_2$ (d) $MgCO_3$

33. Group 2 metals are
(a) harder and have higher cohesive energies and melting points than group 1 metals
(b) softer and have lower cohesive energies and melting points than group 1 metals
(c) softer and have lower cohesive energies and higher melting points than group 1 metals
(d) harder and have higher cohesive energies and lower melting points than group 1 metals

34. The electrolysis of carnallite ($KCl \cdot MgCl_2 \cdot 6H_2O$) yields
(a) potassium ions (b) magnesium ions
(c) magnesium and chlorine (d) potassium and chlorine

35. Calcium chloride reacts with ethyl alcohol to produce
(a) $CaCl_2 \cdot 2C_2H_5OH$ (b) $CaCl_2 \cdot 6C_2H_5OH$
(c) $CaCl_2 \cdot 4C_2H_5OH$ (d) $CaCl_2 \cdot 8C_2H_5OH$

36. The chlorine available in bleaching powder is estimated by
(a) acid-base titration (b) permanganometric titration

(c) dichrometric titration (d) iodometric titration

37. A mixture of $MgCl_2$ and calcined magnesia is called
(a) Sorel cement (b) Portland cement
(c) a double salt (d) dental cement

38. The cyanamide ion $[N{=}C{=}N]^{2-}$ is isoelectronic with
(a) CO_2, and is bent (b) CO_2, and is linear
(c) N_2O, and is V-shaped (d) N_3^-, and is pyramidal

39. Calcium cyanamide is produced by heating
(a) CaC_2 in an electric furnace in an atmosphere of nitrogen at 1100°C
(b) calcium oxide with nitrogen and carbon dioxide at 1000°C
(c) calcium nitrate with calcium oxide at 1500°C
(d) calcium oxide with ammonia and then with carbon at 2000°C

40. Calcium is obtained by the
(a) roasting of limestone
(b) reduction of calcium chloride by carbon
(c) electrolysis of an aqueous solution of calcium chloride
(d) electrolysis of molten calcium chloride

41. Hydrides as well as halides of alkaline earth metals tend to polymerize
(a) strontium (b) calcium
(c) beryllium (d) magnesium

42. Which of the following is not known to exist?
(a) BaO_2 (b) BeO_2 (c) SrO_2 (d) CrO_5

43. In case of alkaline earth metals, which of the following increases with atomic number?
(a) The solubility of their hydroxides
(b) The solubility of their sulphates
(c) Electronegativity
(d) Ionization energy

44. A salt is soluble in water if its
(a) hydration energy is more than its lattice energy
(b) hydration energy is less than its lattice energy
(c) hydration energy is equal to its lattice energy
(d) The solubility of a salt does not depend on the relation between its hydration energy and lattice energy.

45. Which of the following is not a peroxide?
(a) KO_2 (b) CrO_5 (c) Na_2O_2 (d) BaO_2

46. The bicarbonates of group 2 metals are
   (a) easily oxidized by air
   (b) stable only in solution
   (c) unstable in solution
   (d) stable to heat in the solid state

47. Which of the following statements about alkali metals is correct?
   (a) They can be extracted by the reduction of their oxides.
   (b) They can be displaced from the aqueous solutions of their salts by other metals.
   (c) They can be isolated by the electrolysis of the aqueous solutions of their salts.
   (d) They can be isolated by the electrolysis of their molten salts.

48. All group 2 metals dissolve in liquid ammonia to produce a bright blue colour. The colour is due to
   (a) a change in the structure of the ammonia
   (b) d–d transition
   (c) the spectrum of the solvated electrons
   (d) an electronic transition from a lower to a higher energy state

49. The hydration energies of group 2 ions are approximately four times as much as those of group 1 ions. This is due to their
   (a) smaller size and greater nuclear charge
   (b) greater size and lower nuclear charge
   (c) smaller size and lower nuclear charge
   (d) greater size and greater nuclear charge

50. The lattice energies of the carbonates of Mg, Ca, Sr and Ba follow the order
   (a) $MgCO_3 > CaCO_3 > SrCO_3 > BaCO_3$
   (b) $CaCO_3 > SrCO_3 > BaCO_3 > MgCO_3$
   (c) $BaCO_3 > SrCO_3 > CaCO_3 > MgCO_3$
   (d) $SrCO_3 > MgCO_3 > CaCO_3 > BaCO_3$

51. Which of the following is arranged in order of increasing melting point?
   (a) Ca < Be < Mg < Sr   (b) Be < Ca < Sr < Mg
   (c) Mg < Sr < Ca < Be   (d) Sr < Mg < Be < Ca

52. Which of the following statements is incorrect?
   (a) The ionization energy of Be^{2+} is high and its compounds are covalent.
   (b) The ionization energy of Be^{2+} is low and its compounds are covalent.

(c) The compounds formed by Mg, Ca, Sr and Ba are predominantly divalent and ionic.

(d) The ionization energy of Be^{2+} is low, and its compounds are ionic.

53. For compounds with the same anion, the hydration energies of

$$Na^+, K^+, Rb^+, Cs^+ \text{ and } Li^+$$

follow the order

(a) $Cs^+ > Rb^+ > K^+ > Na^+ > Li^+$ (b) $Li^+ > Na^+ > K^+ > Rb^+ > Cs^+$

(c) $K^+ > Na^+ > Li^+ > Cs^+ > Rb^+$ (d) $Li^+ > K^+ > Na^+ > Cs^+ > Rb^+$

54. The raw material used in the Solvay process for the manufacture of sodium carbonate comprises

(a) sodium chloride and carbon dioxide

(b) ammonia and carbon dioxide

(c) sodium chloride, limestone and ammonia

(d) sodium chloride, limestone and carbon dioxide

55. The extents of hydration of the ions of Be, Mg, Ca, Sr and Ba follow the order

(a) $Ca^{2+} > Ba^{2+} > Sr^{2+} > Be^{2+} > Mg^{2+}$

(b) $Be^{2+} > Mg^{2+} > Ca^{2+} > Sr^{2+} > Ba^{2+}$

(c) $Ba^{2+} > Sr^{2+} > Ca^{2+} > Mg^{2+} > Be^{2+}$

(d) $Sr^{2+} > Ba^{2+} > Ca^{2+} > Be^{2+} > Mg^{2+}$

• Type 2 •

Choose the correct options. More than one option is correct.

56. Sodium thiosulphate is prepared by

(a) boiling an Na_2SO_3 solution with S in an acidic medium

(b) boiling an NaOH solution with S

(c) neutralizing an H_2SO_4 solution with NaOH

(d) boiling Na_2SO_3 with S in an alkaline medium

57. The oxide of which of the following metals is amphoteric?

(a) Pb (b) Mg

(c) Ca (d) Al

58. Which of the following are good conductors of electricity in the molten state?

(a) $BeCl_2$ (b) $CaCl_2$ (c) $SrCl_2$ (d) $MgCl_2$

59. Chlorides of which of the following metals crystallize from an aqueous solution as hydrates?

(a) Li (b) Na (c) K (d) Mg

60. Which of the following elements exhibit photoelectric effect?

(a) Na (b) K
(c) Li (d) Cs

61. In the extraction of which of the following metals is amalgamation used?

(a) Ag (b) Au
(c) Cu (d) Fe

62. The fluxes that can be used for the removal of basic impurities like CaO and FeO from an ore are

(a) SiO_2 (b) $Na_2B_4O_7 \cdot 10H_2O$
(c) $MgCO_3$ (d) $CaCO_3$

63. Alkaline earth metals are

(a) more reactive (b) less reducing
(c) more oxidizing (d) less basic

than alkali metals.

64. Which of the following statements are correct?

(a) Alkali metals are better reducing agents than alkaline earth metals.
(b) SF_6 is well known but SH_6 is not known to exist.
(c) BCl_3 is a stronger Lewis acid than BF_3.
(d) Boron forms B^{3+} ions.

65. Na_2SO_4 is soluble in water while $BaSO_4$ is sparingly soluble because

(a) the lattice energy of $BaSO_4$ is more than its hydration energy
(b) the hydration energy of Na_2SO_4 is less than its lattice energy
(c) the hydration energy of Na_2SO_4 is more than its lattice energy
(d) The hydration energy and the lattice energy have no role to play in the solubility of a substance.

66. Which of the following statements are correct for group 1 metals?

(a) They all have one electron in the outer shell preceded by a closed shell containing eight electrons.
(b) The compounds of Group 1 metals are generally ionic and exist as high–melting point solids in which as many ions of opposite charge surround each other as possible.
(c) Their compounds are generally water soluble and white, unless the anions are coloured.
(d) The reactivity increases from lithium to caesium.

67. Which of the following statements is correct for alkali metals?

(a) They can form covalent molecules such as Li_2, Na_2 and K_2. About 1% of these are in the vapour state.

(b) C_6H_5Li is highly reactive.

(c) They form compounds with the liberation of heat.

(d) They all adopt ccp structures.

68. Which of the following statements is correct?

(a) When one electron is removed from a group 2 metal, the ratio of nuclear charge to the number of orbital electrons is increased, so that the remaining electrons are more tightly held.

(b) The energy needed to remove the second electron from a group 2 metal is nearly double that required for the first electron.

(c) When ionic compounds are formed by group 2 metals, energy is released.

(d) When ionic compounds are formed by group 2 metals, energy is absorbed.

69. Which of the following statements is correct?

(a) The solubility of a group 2 salt depends upon the lattice energy of the solid and the hydration energy of the ions.

(b) The solubilities of group 2 fluorides and hydroxides have opposite trends.

(c) The solubilities of most group 2 salts decrease with an increase in the atomic weight of the corresponding metal.

(d) The solubilities of group 2 fluorides and hydroxides increase with molecular weight.

70. Which of the following statements is correct for group 2 metals?

(a) On descending the group the metal ions become larger, and so the lattice energy as well as the hydration energy decrease.

(b) The solubility of their salts increases as the lattice energy decreases, and decreases with hydration energy.

(c) For a substance to dissolve, the hydration energy must exceed the lattice energy.

(d) None of these.

71. Which of the following statements is incorrect for alkali metals?

(a) They do not exist in combination with other elements or radicals.

(b) They are extremely reactive and electropositive.

(c) All of them adopt a bcc structure.

(d) All of them adopt an fcc structure.

72. Magnesium may be called a refractory because it
(a) has high melting point
(b) is a good conductor of heat
(c) is chemically inert as well as an electrical insulator
(d) forms Grignard's reagent

73. Which of the following is correct reaction which is feasible.
(a) $Zn + NaOH + NaNO_3 \longrightarrow Na_2ZnO_2 + N_2 + H_2O$
(b) $Al + NaOH + H_2O \longrightarrow NaAlO_2 + H_2$
(c) $Br_2 + Na_2CO_3 \longrightarrow NaBr + NaBrO_3 + CO_2$
(d) $Sn + NaOH + H_2O \longrightarrow Na_2SnO_3 + H_2$

74. Potassium iodide acts as a reducing agent when treated with
(a) an acidified $K_2Cr_2O_7$ solution
(b) an acidified $KMnO_4$ solution
(c) a $CuSO_4$ solution
(d) a lead acetate solution

75. Which of the following statements is correct for compounds of group 2 metals?
(a) The number of molecules of water of crystallization increases with the size of the metal ions.
(b) The number of molecules of water of crystallization increases as the size of the metal ions decreases.
(c) The number of molecules of water of crystallization decreases as the size of the metal ions increases.
(d) None of these

Answers

1. c	**2.** a	**3.** c	**4.** d	**5.** c
6. d	**7.** a	**8.** d	**9.** b	**10.** d
11. c	**12.** a	**13.** d	**14.** b	**15.** b
16. d	**17.** d	**18.** a	**19.** b	**20.** d
21. c	**22.** c	**23.** c	**24.** a	**25.** b
26. a	**27.** d	**28.** c	**29.** c	**30.** a
31. b	**32.** d	**33.** a	**34.** c	**35.** c
36. d	**37.** a	**38.** b	**39.** a	**40.** d
41. c	**42.** b	**43.** a	**44.** a	**45.** a
46. b	**47.** d	**48.** c	**49.** a	**50.** a

51. c	**52.** d	**53.** b	**54.** c	**55.** b
56. b, d	**57.** a, d	**58.** b, c, d	**59.** a, d	**60.** a, b, d
61. a, b	**62.** a, b	**63.** b, d	**64.** a, b, c	**65.** a, c
66. b, c, d	**67.** a, b, c	**68.** a, b, c	**69.** a, b, c	**70.** a, b, c
71. a, d	**72.** a, b, c	**73.** b, c, d	**74.** a, b, c	**75.** b, c

Hints to More Difficult Problems

1. Fluorides are the most stable and iodides the least.

2. Size factor, i.e. $r_{Li^+} <, \ldots, < r_{Cs^+}$

5. The smallest ion (Li^+) is the least mobile, because it forms big clusters of ions in water.

12. Beryllium is extremely small in size and, according to Fajans' rules, small highly charged ions tend to form covalent compounds.

13. See the answer to Q. 80 of Chapter 1.

23. $MgSO_4 + NH_3 + Na_2HPO_4 \longrightarrow \underset{\text{white ppt}}{Mg(NH_4)PO_4 \downarrow} + Na_2SO_4$

27. $BeCO_3$ has the lowest lattice energy.

30. This is the increasing order of the standard reduction potential of alkali metals.

34. $MgCl_2 \longrightarrow \underset{\substack{\downarrow \\ Mg \\ \text{(cathode)}}}{Mg^{2+}} + \underset{\substack{\downarrow \\ Cl_2 \\ \text{(anode)}}}{2Cl^-}$

KCl is unaffected by the applied voltage and amperage.

36. $Ca(OCl)Cl + H_2O \longrightarrow Ca(OH)_2 + Cl_2$

$Cl_2 + 2KI \text{ (excess)} \longrightarrow I_2 + KCl$

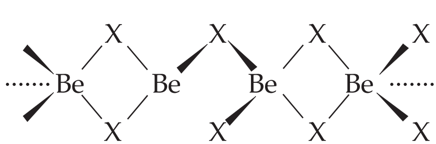
$I_2 + KI \longrightarrow KI_3 \text{ or } K^+ + I_3^-$

$I_3^- + 2S_2O_3^{2-} \longrightarrow S_4O_6^{2-} + 3I^-$

using a starch indicator.

38. $:\ddot{O}{=}C{=}\underset{\cdot\cdot}{\overset{\cdot\cdot}{O}}$ (linear)

41.



The coordination number of Be in these chains is not exactly four. The deviations from the ideal tetrahedral angle for a four-coordinate Be atom depend on the nature of the bridging group, and are related to the presence or absence of lone pairs on the bridging group.

45. KO_2 is a superoxide ($K^+O_2^-$), and the rest are peroxides.

$$(:\ddot{\underset{\cdot\cdot}{\bar{O}}}-\ddot{\underset{\cdot\cdot}{\bar{O}}}:).$$

47. Because of their degree of reactivity.

50. The smaller the size of the cation, the greater is the lattice energy.

51. The melting point of a metal depends on how closely packed a structure it has.

53. The smaller the size of the cation, the greater is the hydration energy.

57. Pb as well as Al are amphoteric because they react with acids as well as alkalis to produce H_2 gas.

58. They are ionic salts in the fused state.

59. The smaller the size of the cation, the greater is the hydration power. The corresponding chlorides form hydrated salts.

62. They are acidic.

63. Alkaline earth metals have lower standard reduction potentials than alkali metals.

67. The ions of alkali metals have small radii.

74. KI is a reducing agent,

$$2I^- \rightarrow I_2 + 2e$$

and $Cr_2O_7^{2-}/H^+$, MnO_4^-/H^+ and Cu^{2+} are all oxidizing agents. So, I^- reduces them, and is itself oxidized.

❑

4

Boron

• Type 1 •

Choose the correct option. Only one option is correct.

1. Which of the following compounds is an important catalyst as well as a Lewis acid?

(a) Al_2S_3 (b) S_4N_4

(c) N_2H_4 (d) BF_3

2. Amorphous boron is prepared by heating B_2O_3 with

(a) Mn (b) Hg

(c) Mg (d) SiO_2

3. Which of the following ions does not exist in an aqueous solution?

(a) Pb^{2+} (b) Sn^{4+} (c) B^{3+} (d) Tl^{+}

4. Among the following, which shows the correct order of magnitude of inert-pair effect?

(a) $B < Al < Ga < In < Tl$ (b) $Ga > In > Tl < B > Al$

(c) $Ga < In < Tl < B < Al$ (d) $Be \approx Al > Ga > Tl > In$

5. Boron has an extremely high melting point because of

(a) the strong van der Waals forces between its atoms

(b) the strong binding forces in the covalent polymer

(c) its ionic crystal structure

(d) allotropy

6. Orthoboric acid contains

(a) pyramidal BO_3^{3-} units (b) linear BO_3^{3-} units

(c) T-shaped BO_3^{3-} units (d) triangular BO_3^{3-} units

7. A boron carbide rod is used in a nuclear reactor because boron (^{10}B) has a very

(a) low area of cross-section for capturing neutrons

(b) high area of cross-section for capturing neutrons

(c) low area of cross-section for capturing protons

(d) high area of cross-section for capturing neutrinos

8. Which of the following statements is incorrect?

(a) Boron carbide is used as an abrasive.

(b) Boron is used to increase the hardenability of steel.

(c) Boron sesquioxide, B_2O_3, is used in the manufacture of borosilicate glass.

(d) Orthoboric acid undergoes intramolecular hydrogen bonding.

9. On hydrolysis, diborane produces

(a) $H_3BO_2 + H_2O_2$ (b) $H_3BO_3 + H_2$

(c) $B_2O_3 + O_2$ (d) $H_3BO_3 + H_2O_2$

10. Which of the following statements is correct?

(a) Borosilicate glass is not heat resistant.

(b) Peroxoborate is stable to high heat.

(c) Borosilicate glass has a lower coefficient of thermal expansion and is easier to work with than normal soda glass.

(d) Soda-free glass fibre is made from boric oxide, sodium silicate and phosphorus.

11. Boron nitride is a

(a) white solid with a diamond-like structure

(b) slippery white solid with a layered structure similar to that of graphite

(c) covalent liquid and is structurally similar to carbon monoxide

(d) soft low-melting solid with a rock-salt–like structure

12. B_2H_6 reacts with $(CH_3)_3N$ to produce

(a) $BH_3^{+}\bar{N}(CH_3)_3$ (b) $B_2H_6^{+}\bar{N}(CH_3)_2CH_3 \cdot BH_3$

(c) $(CH_3)_3\overset{+}{N}\overset{-}{B}H_3$ (d) $\overset{-}{B}H_3\overset{+}{N}(CH_3)_2CH_3BH_3$

13. The colour of the borax bead is due to the formation of a/an

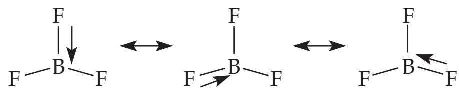
(a) glass-like metal metaborote bead

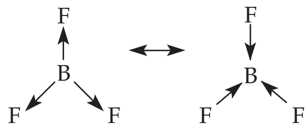
(b) hard boric oxide crystal

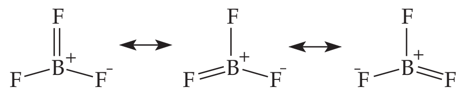
(c) opaque metal hexaborate bead

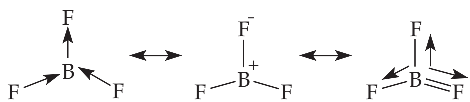
(d) glass-like metal orthoborate bead

14. Which of the following structures correctly represents the boron trifluoride molecule?

(a) 

(b) 

(c) 

(d) 

15. By which of the following reactions is borazine prepared?

(a) $B_2H_6 + NH_3$ (excess) $\xrightarrow{\text{low temperature}}$

(b) $B_2H_6 + NH_3$ (excess) $\xrightarrow{\text{high temperature}}$

(c) $B_2H_6 + NH_3 \xrightarrow[\text{high temperature}]{(\text{ratio } 2NH_3 : 1B_2H_6)}$

(d) None of these

16. Which of the following pairs contains structurally dissimilar substances?

(a) Borazine and benzene

(b) Diborane and hydrazine

(c) NaCl and NiO

(d) Graphite and cadmium iodide

17. Which of the following statements is incorrect in the context of the B—F bond in BF_3?

(a) All the three B—F bond lengths are equal and each of them is shorter than the sum of the covalent radii of boron and fluorine.

(b) The bond energy of the B—F bond is very high, higher than for any other single bond.

(c) The unusual shortness and strength of the B—F bond may be explained by a pπ-pπ interaction between boron and fluorine atoms.

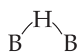
(d) The unusual shortness and strength of the bonds may be explained by a pπ-dπ interaction between the atoms of boron and fluorine.

18. Which of the following statements is incorrect in relation to the structure of diborane?

(a) The terminal B—H bond distances are the same as the bond distances measured in compounds which are not electron-deficient, and which have no bridge structure.

(b) The terminal B—H bond is a 2-centre 3-electron bond.

(c) The terminal B—H bond is a 2-centre 2-electron bond.

(d) The bridge  is a 3-centre 2-electron bond.

19. Which of the following statements is incorrect?

(a) $B(OH)_3$ partially reacts with water to form H_3O^+ and $[B(OH)_4]^-$, and behaves like a weak acid.

(b) $B(OH)_3$ behaves like a strong monobasic acid in the presence of sugars, and this acid can be titrated against an NaOH solution using phenolphthalein as an indicator.

(c) $B(OH)_3$ does not donate a proton and hence does not form any salt with NaOH.

(d) $B(OH)_3$ reacts with NaOH, forming $Na[B(OH)_4]$.

20. Which of the following statements is incorrect?

(a) B_2H_6 is not an electron-deficient molecule.

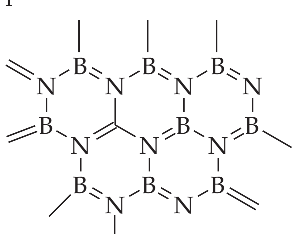
(b) The dipole moment of BF_3 is zero.

(c) The hydroboration of alkenes and subsequent oxidation with H_2O_2 and NaOH leads to the *cis* hydration of the carbon-carbon double bond with apparent anti-Markovnikov addition to give alcohols.

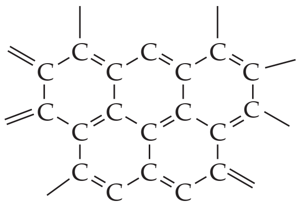
(d) BF_3 and BrF_3 molecules have different shapes.

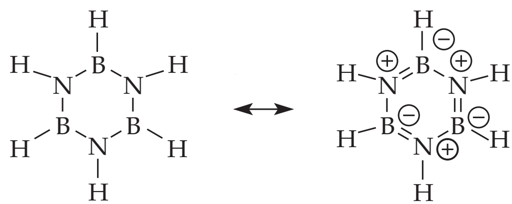
21. Which of the following structures does not represent the compound given in parentheses?

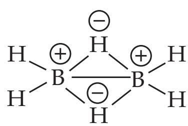
(a)



(boron nitride)

(b)  (graphite)

(c)  (borazine)

(d)  (diborane)

22. Among the boron halides, which is the strongest Lewis acid?

(a) BBr_3 (b) BCl_3

(c) BI_3 (d) BF_3

23. Which of the following statements is correct in the context of diborane (B_2H_6)?

(a) There are 12 valence electrons—three from each of the two boron atoms and six from the six hydrogen atoms.

(b) Two of the six hydrogen atoms form two bridges between two boron atoms.

(c) The two bridging hydrogen atoms are in a plane perpendicular to the rest of the molecule and prevent rotation between the two boron atoms.

(d) All of these.

• <u>*Type 2*</u> •

Choose the correct options. More than one option is correct.

24. Which of the following compounds are acidic?

(a) $B(OH)_3$ (b) $Al(OH)_3$

(c) BF_3 (d) SiO_2

25. Which of the following compounds react with BF_3?

(a) Ethers (b) B_2O_3

(c) Al_2Cl_6 (d) NH_3

26. Which of the following species have tetrahedral structures?

(a) B_2H_6 (b) $B_3N_3H_6$

(c) BH_4^- (d) $AlCl_4^-$

27. Which of the following compounds react with B_2H_6?

(a) Cl_2 (b) CO

(c) NH_3 (d) $(CH_3)_3N$

28. Which of the following compounds contain boron?

(a) Borax (b) Colemanite

(c) Cristoballite (d) Kernite

29. Which of the following compounds can be made from borax?

(a) H_3BO_3 (b) B_2O_3

(c) $LiBH_4$ (d) BCl_3

30. Which of the following statements are correct?

(a) Boric acid is a hydrogen-bonded molecule.

(b) Boric acid combines with CuO to give metaborate in the borax bead test.

(c) Al_2O_3 is more acidic than B_2O_3.

(d) Al_2O_3 is amphoteric and B_2O_3 is acidic.

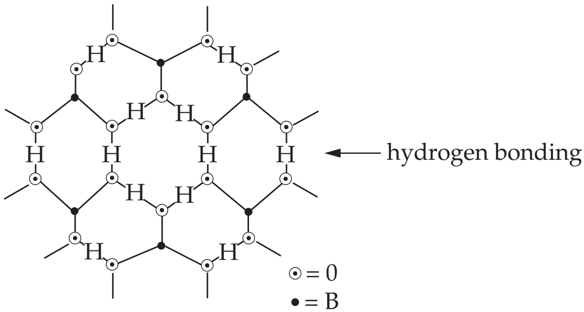
Answers

1. d	**2.** c	**3.** c	**4.** a	**5.** b
6. a	**7.** b	**8.** d	**9.** b	**10.** c
11. b	**12.** c	**13.** a	**14.** a	**15.** c
16. b	**17.** d	**18.** b	**19.** c	**20.** a
21. d	**22.** a	**23.** d	**24.** a, c	**25.** a, b, c, d
26. c, d	**27.** a, b, c, d	**28.** a, b, d	**29.** a, b, c, d	**30.** a, b, d

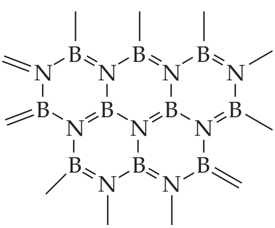
Hints to More Difficult Problems

3. Boron forms covalent compounds.

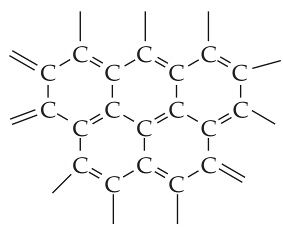
8.



11.



Boron nitride



Graphite

12. B_2H_6 is electron-deficient and $(CH_3)_3N$ contains a lone pair of electrons. Hence both react together according to the Lewis acid-base concept.

22. Certain properties of the BX_3 adducts with donor molecules suggest that the donor-boron bonds may themselves increase in strength in the order $BF_3 < BCl_3 < BBr_3$.

25. BF_3 is a Lewis acid and the other compounds are Lewis bases. Hence it reacts with all of them.

27. Same explanation as given for the answer to Q. 25

28. The compounds shown in options (a), (b) and (d) are minerals containing boron; cristobalite has the formula SiO_2.

❑

5

Carbon

• Type 1 •

Choose the correct option. Only one option is correct.

1. In the carbon family the elements other than carbon do not form pπ-pπ bonds because the atomic orbitals are too
   (a) small and diffuse to undergo effective lateral overlap
   (b) large and diffuse to undergo effective lateral overlap
   (c) large and far too less diffuse to overlap linearly
   (d) small to overlap both laterally and linearly

2. The stability of the tetrahalides of carbon decreases in the order
   (a) $CF_4 > CCl_4 > CBr_4 > CI_4$ (b) $CCl_4 > CBr_4 > CF_4 > CI_4$
   (c) $CI_4 > CCl_4 > CBr_4 > CF_4$ (d) $CBr_4 > CF_4 > CCl_4 > CI_4$

3. Graphite has a layered structure. The distance between the layers is
   (a) 135 pm (b) 435 pm (c) 225 pm (d) 335 pm

4. The interlayer distance in graphite is
   (a) very small, the layers being tightly packed
   (b) many times larger than the covalent radius of carbon
   (c) more than twice the covalent radius of carbon
   (d) the same as the covalent radius of carbon

5. Carbon forms a large number of compounds due to its
   (a) tetravalency (b) variable valency
   (c) large chemical affinity (d) property of catenation

6. Which of the following statements is incorrect for graphite?
   (a) Its density is lower than that of diamond.

(b) It has a layered structure and the bonding between the layers is very weak.

(c) Its layers are very tightly packed, almost without any space between them.

(d) It cleaves easily between the layers which accounts for the remarkable softness of the crystals.

7. Which of the following statements is correct?

(a) Graphite is thermodynamically more stable than diamond.

(b) Diamond is thermodynamically more stable than graphite.

(c) Graphite has such a high thermodynamical stability that diamond spontaneously changes into graphite in ordinary conditions.

(d) Graphite and diamond have equal thermodynamic stability.

8. Among the following, the tendency for catenation decreases in the order

(a) C > Si > Ge = Sn > Pb (b) Si > C > Ge = Sn > Pb

(c) C > Ge > Sn > Si > Pb (d) C > Pb > Sn > Ge > Si

9. In the equilibrium C(s, diamond) $\rightleftharpoons$ C(s, graphite) + heat (density of diamond and graphite are 3.5 and 2.3 g/cm^3 respectively), the equilibrium will be shifted to the left at

(a) low temperature and very high pressure

(b) high temperature and low pressure

(c) high temperature and very high pressure

(d) low temperature and low pressure

10. In the carbon family the melting points of the elements decrease on descending the group because the interatomic bonds become

(a) stronger as the size of the atom increases

(b) weaker as the size of the atom decreases

(c) stronger as the size of the atom decreases

(d) weaker as the size of the atom increases

11. Which of the following elements forms only three hydrides?

(a) C (b) Si

(c) Ge (d) Pb

12. Which of the following is the most ionic?

(a) CCl_4 (b) $PbCl_2$

(c) $PbCl_4$ (d) $SiCl_4$

13. Carbon atoms in diamond are bonded to each other in a

(a) linear configuration (b) planar configuration

(c) octahedral configuration (d) tetrahedral configuration

14. Which of the following statements is correct?

(a) Aluminium carbide as well as beryllium carbide produce methane gas on treatment with water.

(b) On reacting with water, calcium carbide (CaC_2) produces acetylene while magnesium carbide (Mg_2C_3) gives propyne.

(c) Calcium carbide has a lattice similar to that of NaCl, but the unit cell is elongated in one direction.

(d) All of these

15. CS_2 reacts with Cl_2 to produce

(a) CCl_4 and S_2Cl_2 (b) CCl_2 and SCl_4

(c) CCl_4 and SCl_2 (d) CCl_4 and SCl_6

16. Which of the following metal carbides may be called a methanide?

(a) CaC_2 (b) Mg_2C_3

(c) Al_4C_3 (d) BaC_2

17. Calcium carbide is manufactured by heating

(a) calcium with carbon

(b) lime with coke

(c) calcium with carbon monoxide

(d) calcium chloride with coke

18. In carbon-60 all carbon atoms are

(a) sp^2-hybridized with a truncated icosahedron shape

(b) sp^3-hybridized with a square antiprism shape

(c) sp^2-hybridized with a diamond shape

(d) sp^2-hybridized with a graphite-like shape

19. Carbon-60 contains

(a) 20 pentagons and 12 hexagons

(b) 12 pentagons and 20 hexagons

(c) 30 pentagons and 30 hexagons

(d) 24 pentagons and 36 hexagons

20. The crystal structure of calcium carbide resembles that of

(a) rutile (TiO_2) (b) fluorite (CaF_2)

(c) silica (SiO_2) (d) rock salt (NaCl)

21. Which of the following metal carbonates produces the corresponding metal on strong heating?

(a) $FeCO_3$ (b) Li_2CO_3

(c) $CaCO_3$ (d) Ag_2CO_3

22. C_{60} can be regarded as a huge ball made up of
(a) several conjugated alkene units rather than an aromatic molecule
(b) graphite units
(c) several aromatic benzene molecules
(d) several tetrahedrons

23. The correct order of increasing carbon-oxygen bond length among CO, CO_3^{2-} and CO_2 is
(a) $CO_3^{2-} < CO_2 < CO$ (b) $CO_2 < CO_3^{2-} < CO$
(c) $CO < CO_3^{2-} < CO_2$ (d) $CO < CO_2 < CO_3^{2-}$

24. CO_3^{2-} and SO_3^{2-} can be distinguished from each other by the production of CO_2 and SO_2 respectively upon using
(a) baryta water (b) limewater
(c) acidified dichromate (d) sulphamic acid

25. On hydrolysis, magnesium carbide produces
(a) acetylene (b) butyne (c) propane (d) propyne

26. Which of the following statements is incorrect?
(a) The carbon dioxide molecule behaves as a nonpolar molecule even though two of its resonating structures,
$\overset{-}{O}—C\equiv\overset{+}{O}$ and $\overset{+}{O}\equiv C—\overset{-}{O}$, are dipolar.
(b) Carbon dioxide is the anhydride of the unstable dibasic acid $O=C(OH)_2$
(c) The carbon dioxide molecule is linear because the carbon atom utilises its sp orbitals to form σ-bonds.
(d) The carbon atom is sp^2-hybridized in the CO_2 molecule as well as the molecule of its hydrate H_2CO_3.

27. Which of the following statements is correct?
(a) An aqueous solution of sodium carbonate is neither acidic nor basic.
(b) An aqueous solution of sodium carbonate is alkaline because, being a base, the carbonate ion picks up the hydrogen ion from water releasing a hydroxide ion, making the solution alkaline.
$$CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$$
(c) An aqueous solution of sodium carbonate is acidic because, being very electropositive, the sodium ion picks up the hydroxide ion from water to release a hydrogen ion, making the solution acidic
$$2Na^+ + 2H_2O \longrightarrow 2NaOH + 2H^+$$
(d) An aqueous solution of sodium carbonate is acidic because the carbonate ion reacts with water to form carbonic acid.
$$CO_3^{2-} + 2H_2O \rightleftharpoons H_2CO_3 + 2OH^-$$

28. Which of the following compounds is used as an abrasive?

(a) CaNCN (b) Al_4C_3 (c) CaC_2 (d) SiC

29. A crystalline hydrate $CO_2 \cdot 8H_2O$ is formed at

(a) 0°C and 1 atmospheric pressure

(b) 100°C and very high atmospheric pressure

(c) 100°C and 1 atmospheric pressure

(d) 0°C and very low pressure

30. Carbon monoxide is poisonous because it

(a) dries up

(b) reduces the organic matter of tissues

(c) combines with haemoglobin and causes deficiency of oxygen in blood

(d) combines with the O_2 present in blood to form CO_2

31. Solid CO_2 is produced as white snow by

(a) cooling the gas below its inversion temperature.

(b) cooling the gas below its Boyle's temperature

(c) expanding the gas at high temperature

(d) the adiabatic expansion of the compressed gas by allowing it to escape through an orifice in the container

32. In the carbon monoxide molecule, carbon and oxygen are linked by

(a) only σ-bonds (b) only π-bonds

(c) σ- as well as π-bonds (d) no σ- and π-bonds

33. Sodium hydroxide reacts with carbon monoxide to produce

(a) CO_2 (b) $(COONa)_2$

(c) HOOC·COONa (d) HCOONa

34. Which of the following solutions can absorb carbon monoxide under ordinary conditions?

(a) Baryta water

(b) A dilute ammonia solution

(c) Limewater

(d) An ammoniacal cuprous chloride solution

35. The structure of SiC is

(a) that of a layered lattice (b) linear

(c) tetrahedral (d) square planar

36. Which of the following is an industrial fuel?

(a) Water gas ($CO + H_2$) (b) Producer gas ($CO + N_2$)

(c) Coal gas ($CO + H_2 + CH_4 + CO_2$)
(d) All of these

37. "Synthesis gas" is a mixture of
(a) carbon monoxide and hydrogen
(b) carbon monoxide and nitrogen
(c) carbon monoxide and steam
(d) methane and hydrogen

38. Carbon suboxide (C_3O_2) may be obtained by heating
(a) malonic acid with P_4O_{10}
(b) malic acid with P_4O_{10}
(c) oxalic acid strongly
(d) maleic acid with P_4O_{10}

39. In graphite, the hybridization state of each carbon atom and the π-bond order of each carbon-carbon bond are, respectively,
(a) sp and $\frac{1}{2}$
(b) sp^2 and $\frac{1}{3}$
(c) sp^3 and 1
(d) sp^2 and $\frac{3}{2}$

40. The diamond molecule contains
(a) sp^2-hybridized carbon atoms connected by single bonds
(b) sp^2-hybridized carbon atoms connected by double bonds
(c) sp^3-hybridized carbon atoms connected by single bonds
(d) sp^3- and sp^2-hybridized carbon atoms connected by single bonds

• *Type 2* •

Choose the correct options. More than one option is correct.

41. Graphite is a
(a) bad conductor of heat
(b) good conductor of electricity
(c) good conductor of heat
(d) good insulator

42. Which of the following are used as moderators in nuclear reactors?
(a) Graphite
(b) Paraffin
(c) Heavy water
(d) None of these

43. When oxalic acid is heated with concentrated H_2SO_4, it produces
(a) CO
(b) SO_2 and CO_2
(c) CO and SO_3
(d) CO_2

44. Methane is obtained by the hydrolysis of

(a) Be_2C (b) B_4C

(c) Li_2C_2 (d) Al_4C_3

45. Which of the following ions are regarded as ionic carbides?

(a) C^{4-} (b) C_2^{2-}

(c) C_3^{4-} (d) C_4^{3-}

46. Which of the following halides of carbon are solids?

(a) CF_4 (b) CCl_4

(c) CBr_4 (d) CI_4

47. Which of the following oxides of carbon are stable?

(a) CO (b) CO_2

(c) C_3O_2 (d) C_2O_3

48. Which of the following statements are correct?

(a) The name buckminsterfullerene was given to C_{60}.

(b) The comon name for C_{60} is 'bucky ball'.

(c) C_{60} has a geodesic dome structure.

(d) Solid C_{60} has a cubic close-packed structure.

49. Which of the following molecules have zero dipole moment?

(a) CS_2 (b) CO_2

(c) CCl_2 (d) CH_2Cl_2

50. Buckminsterfullerene is prepared by

(a) the pulsed laser vapourization of graphite

(b) vapourizing carbon by resistive heating

(c) passing an arc discharge between carbon electrodes in a tube containing helium at 100 torr

(d) none of these

Answers

1. b	**2.** a	**3.** d	**4.** c	**5.** d
6. c	**7.** a	**8.** a	**9.** c	**10.** d
11. c	**12.** b	**13.** d	**14.** d	**15.** a
16. c	**17.** b	**18.** a	**19.** b	**20.** d
21. d	**22.** a	**23.** d	**24.** c	**25.** d
26. d	**27.** b	**28.** d	**29.** a	**30.** c

31. d	**32.** c	**33.** d	**34.** d	**35.** c
36. d	**37.** a	**38.** a	**39.** b	**40.** a
41. b, c	**42.** a, b, c	**43.** a, d	**44.** a, d	**45.** a, b, c
46. c, d	**47.** a, b, c	**48.** a, b, c, d	**49.** a, b	**50.** a, b, c

Hints to More Difficult Problems

7. The free energy of formation of graphite is 2.9 kJ mol^{-1} lower than that of diamond at 300 K and 1 atm pressure.

9. Apply the Le Chatelier principle.

12. Apply Fajans' rules.

16. Al_4C_3 reacts with water to produce methane (CH_4).

$$Al_4C_3 + 12H_2O \longrightarrow 4Al(OH)_3 + 3CH_4$$

Therefore, it may be called a methanide.

19. Use Euler's formula for any C_n cluster (n even and greater than 22). Such clusters have at least one closed hollow cage consisting of 12 pentagons and $(n - 20)/2$ hexagons. For C_{60} $n = 60$. Then $(60 - 20)/2 = 20$ (number of hexagons).

24. SO_2 turns acidified $K_2Cr_2O_7$ solution green whereas CO_2 will have no effect on such a solution.

31. Consider the Joule–Thomson effect.

32. $:C\overset{\pi}{\underset{\pi}{\equiv}}\sigma O:$

38. $\underset{\text{Malonic acid}}{HO_2CCH_2CO_2H} \xrightarrow[150°C]{P_4O_{10}} \underset{\text{carbon suboxide}}{O{=}C{=}C{=}C{=}O} + 2H_2O$

41. The continuous π system in each layer of graphite makes it a good conductor of electricity.

42. C_2O_3 does not exist.

49. Both CS_2 and CO_2 have a linear structure.

$$S{=}C{=}S \quad \text{and} \quad O{=}C{=}O$$

The vector sum of the individual dipole moments, and hence the dipole moments of the molecules, are zero.

❑

6

Silicon

• Type 1 •

Choose the correct option. Only one option is correct.

1. Silicon carbide (SiC) is known as
(a) quartz
(b) tridynite
(c) corundum
(d) carborundum

2. Very pure silicon is prepared by
(a) reducing pure silicon tetrachloride with magnesium
(b) decomposing $K_2[SiF_6]$
(c) heating SiO_2 with KF
(d) the electrolysis of SiO_2 in SiF_4

3. Very pure silicon is an insulator, but becomes a *p*-type or an *n*-type semiconductor when doped with a
(a) group 1 and a group 12 element respectively
(b) group 13 and a group 15 element respectively
(c) group 12 and a group 16 element respectively
(d) group 4 and a group 5 element respectively

4. Which of the following bonds has the highest bond energy?
(a) Si—C
(b) Si—H
(c) Si—O
(d) Si—Si

5. Glass is
(a) a superheated liquid
(b) a supercooled liquid
(c) an organosilicon polymer
(d) a crystalline semisolid

6. Glass is soluble in
(a) PbF_4
(b) $B(OH)_3$
(c) HF
(d) concentrated HNO_3

7. Silicon shows a diagonal relation with
(a) magnesium (b) phosphorus
(c) carbon (d) boron

8. Which of the following halides easily undergoes hydrolysis?
(a) AgCl (b) NF_3
(c) $SiCl_4$ (d) CF_4

9. Silicate minerals are classified according to the manner of linking of
(a) SiO_4^{6-} tetrahedral units (b) SiO_4^{4-} tetrahedral units
(c) $(Si_2O_7^{2-})_n$ units (d) $(SiO_3)_n^{4n}$ triangular units

10. Which of the following is a purely acidic oxide?
(a) SiO_2 (b) SnO_2
(c) PbO (d) MnO_2

11. Carbon dioxide is a gaseous molecule while SiO_2 is a three-dimensional–network solid because
(a) CO_2 molecules are held by strong van der Waals forces whereas SiO_2 is an ionic solid
(b) CO_2 has a structure like that of CaC_2, and SiO_2 has a rutile structure
(c) CO_2 exists as a discrete molecule due to the formation of double bonds between the carbon and oxygen atoms by 2p-2p π-bonding while silicon cannot form such double bonds with oxygen because the 3p-2p π overlap is not efficient; thus SiO_2 forms an infinite three-dimensional structure
(d) CO_2 molecules are held by 2p-3p π-bonding and SiO_2 molecules are held by 3p-3d π overlap; thus SiO_2 forms an infinite three-dimensional structure

12. Which of the following molecules is coordinatively saturated?
(a) $AlCl_3$ (b) $SiCl_4$
(c) CCl_4 (d) PbI_4

13. Which of the following species is not coordinatively saturated?
(a) SiF_6^{2-} (b) CH_4
(c) PCl_6^- (d) SnF_5^-

14. Often a ground-glass stopper gets stuck in the neck of a glass bottle containing an NaOH solution. The reason is that
(a) there are particles of dirt in between
(b) a solid silicate is formed in between by the reaction of the SiO_2 of glass with NaOH

(c) solid Na_2CO_3 is formed in between by reaction of the CO_2 of air and NaOH

(d) glass contains a boron compound which forms a precipitate with the NaOH solution

15. Which of the following orthosilicates is known as willemite?

(a) $Zn_3[SiO_4]_2$ (b) $Mn_2[SiO_4]$

(c) $W_2[SiO_4]$ (d) $Zn_2[SiO_4]$

16. $SiCl_4$ is easily hydrolysed by water whereas CCl_4 is stable towards hydrolysis in water because

(a) CCl_4 exists as a molecule whereas $SiCl_4$ is ionic

(b) the C—Cl bond is stronger than the Si—Cl bond

(c) silicon has a 3d orbital available for further coordination with water whereas carbon has no d orbital for bonding

(d) silicon is more electropositive than carbon

17. Carbon shows strong catenation while silicon shows little or no catenation because

(a) silicon is a metalloid and carbon is a nonmetal

(b) silicon forms ionic compounds whereas carbon forms covalent compounds

(c) the Si—Si bond is stronger than the C—C bond

(d) the C—C bond is stronger than the Si—Si bond

18. Which of the following molecules is not a donor?

(a) $(C_2H_5)_2NH$ (b) $(C_2H_5)_3N$

(c) $(SiH_3)_3N$ (d) C_2H_5OH

19. The hybridization state of nitrogen atoms in the molecules $(CH_3)_3N$ and $(SiH_3)_3N$ are

(a) respectively sp^3 and sp^2 (b) respectively sp^2 and sp^3

(c) both sp^2 (d) both sp^3

20. The lone pair of electrons in the nitrogen atoms of the molecules $(CH_3)_3N$ and $(SiH_3)_3N$ are accommodated respectively in the

(a) sp^3 orbital and sp^2 orbital (b) sp^3 orbital and p orbital

(c) p orbital and sp^2 orbital (d) p orbital in both the cases

21. The shapes of the molecules of $(CH_3)_3N$ and $(SiH_3)_3N$ are respectively

(a) pyramidal

(b) planar triangular

(c) planar triangular and pyramidal

(d) pyramidal and planar triangular

22. The oxidation numbers of Si in $Si_3O_9^{6-}$ and $Si_6O_{18}^{12-}$ respectively are

(a) –4, –4 (b) +4, +2

(c) +4, +4 (c) +4, +6

23. Which of the following statements is correct for silicon? It

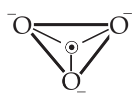
(a) forms molecular halides that are not hydrolysed.

(b) forms strong but unconjugated multiple bonds of the pπ-dπ variety, especially with O and N.

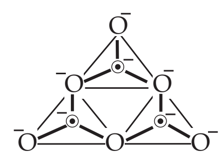
(c) does not undergo coordination number expansion

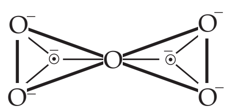
(d) forms an oxide (SiO_2) that is amphoteric and has a GaAs structure.

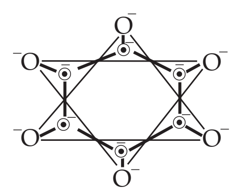
24. Which of the following represents a pyrosilicate structure?

(a) 

O Oxygen
• Silicon

(b) 

(c) 

(d) 

25. Which of the following statements is incorrect?

(a) The octahedral SiF_6^{2-} ion is the only halogenocomplex of silicon, and the bonding in it involves sp^3d^2 hybridization.

(b) Fluorosilicic acid, H_2SiF_6, known only in solution, is a strong acid.

(c) Silicon is more electropositive than carbon.

(d) The formula of tetramethyl silane is $(CH_3)_4SiH_4$.

26. Silicones are a group of organosilicon polymers containing

(a) Si—O—Si linkages (b) O—Si—O linkages

(c) Si—C—Si linkages (d) Si—Si—O linkages

27. Which of the following statements is incorrect?

(a) The hydrolysis of $(CH_3)_3SiCl$ gives a disiloxane.

(b) The hydrolysis of $(CH_3)_2SiCl$ gives a chain compound.

(c) The hydrolysis of CH_3SiCl_3 gives a cross-linked polymer.

(d) The hydrolysis of $(CH_3)_2SiCl_2$ gives $(CH_3)_2SiO_2$.

28. Which of the following pairs of ions do not represent cyclic and chain silicates?

(a) $Si_2O_7^{2-}$ and $(SiO_3)_n^{2n-}$ (b) $S_3O_9^{6-}$ and $(Si_4O_{11})_n^{6n-}$

(c) $Si_2O_7^{2-}$ and $(Si_2O_5)_n^{2n-}$ (d) $Si_2O_7^{7-}$ and $(SiO_3)_n^{2n-}$

29. Which of the following statements is incorrect in the context of silicones?

(a) They are more stable to heat than other polymers.

(b) They are strongly water-repellent, are good electrical insulators, and have nonsticking and antiforming properties.

(c) The Si—O bond energy is high.

(d) The Si—O bond energy is low.

30. Silicon carbide reacts with concentrated NaOH in the presence of air to produce

(a) $Na_2SiO_3 + H_2$ (b) $Na_2SiO_3 + Na_2CO_3$

(c) $Na_2SiO_2 + H_2$ (d) $Na_2SiO_4 + O_2$

• Type 2 •

Choose the correct options. More than one option is correct.

31. Pure SiO_2 occurs as

(a) quartz (b) cristobalite

(c) colemanite (d) siderite

32. Which of the following have cyclic silicate structures?

(a) $Si_3O_9^{6-}$ (b) SiO_4^{2-}

(c) $Si_6O_{18}^{12-}$ (d) $(Si_4O_{11}^{6-})_n$

33. Which of the following elements form hydrides?

(a) Si (b) Ge

(c) Pb (d) C

34. Which of the following halides are hydrolysed by water?

(a) $SiCl_4$ (b) CCl_4

(c) $AlCl_3$ (d) CF_4

35. Which of the following molecules have a V-shaped structure?

(a) $SnCl_4$ (b) $SnCl_2$

(c) COS (d) $PbCl_2$

Answers

1. d	**2.** a	**3.** b	**4.** c	**5.** b
6. c	**7.** d	**8.** c	**9.** b	**10.** a
11. c	**12.** c	**13.** d	**14.** b	**15.** d
16. c	**17.** d	**18.** c	**19.** a	**20.** b
21. d	**22.** c	**23.** b	**24.** c	**25.** d
26. a	**27.** c	**28.** b	**29.** d	**30.** c
31. a, b	**32.** a, c	**33.** a, b, c, d	**34.** a, c	**35.** b, d

Hints to More Difficult Problems

6. Glass contains silica. It dissolves in HF forming $H_2[SiF_6]$ (hydrofluorosilicic acid).

8. $SiCl_4$ is readily hydrolysed. Si can use a d orbital to form a five-coordinate intermediate to produce $SiCl_6^{2-}$.

12. CCl_4 does not undergo coordination number expansion.

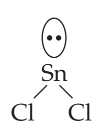
18. Trisilylamine or $(SiH_3)_3N$ involves pπ-dπ bonding, because the bond forms between full p orbitals and an empty d orbital. This shortens the N–Si bond lengths. Since nitrogen does not have a lone pair of electrons, the molecule is not a donor.

22. In $Si_3O_9^{6-}$, $3x - 18 = -6 \Rightarrow 3x = 12 \Rightarrow x = +4$

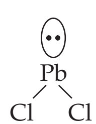
In $Si_6O_{18}^{12-}$, $6x - 36 = -12 \Rightarrow 6x = 24 \Rightarrow x = +4$

34. Both use a d orbital and undergo coordination-number expansion.

35.



V-shaped



V-shaped

❑

7

Nitrogen and Phosphorus

• *Type 1* •

Choose the correct option. Only one option is correct.

1. The nitrogen molecule is isoelectronic with

(a) CO^-, CN^+ and NO_2^+ (b) CO, CN^- and NO^+

(c) CO^+, N_2O and O_2^{2-} (d) O_2^+, O_2^- and CO^+

2. N_2 is prepared commercially by

(a) the fractional distillation of liquefied air

(b) heating ammonium dichromate

(c) heating a mixture of ammonium chloride and sodium nitrite

(d) the serpeck process

3. Which of the following is an ionic compound?

(a) NI_3 (b) NF_3 (c) NCl_3 (d) BiF_3

4. Active nitrogen can be made by passing an electric spark through N_2 gas at

(a) very low pressure (2 mm of Hg)

(b) high pressure

(c) very low temperature

(d) ordinary pressure

5. Which of the following properties does nitrogen not exhibit?

(a) Low boiling point (b) Hydrogen bonding

(c) Catenation (d) Supporter of life

6. Nitrous oxide is prepared by the thermal decomposition of

(a) dinitrogen tetroxide (b) ammonium nitrate

(c) ammonium nitrite (d) diazomethane

7. Which of the following statements is correct in the context of the N_2O molecule?

(a) The N—N bond is longer than the N—O bond.
(b) The N—N bond is as long as the N—O bond.
(c) The N—N bond has no π character.
(d) The N—N bond is shorter than the N—O bond.

8. Which of the following pairs consists of species of equal bond order?

(a) N_2 and CO (b) N_2 and CN^+
(c) CO^- and N_2^+ (d) N_2 and NO^+

9. Which of the following statements is incorrect for nitric oxide?

(a) It is an anhydride of nitrous acid.
(b) It is a paramagnetic molecule.
(c) It does not dimerize.
(d) It has a dipole moment of 0.12 D.

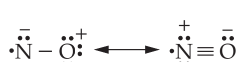
10. The bond length of N—O is 1.15 Å, which is intermediate between those of a

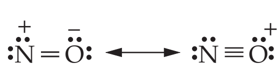
(a) single bond and a double bond between N and O
(b) double bond and a triple bond between N and O
(c) carbon-carbon single bond and a carbon-carbon double bond
(d) carbon-carbon double bond and a carbon-carbon triple bond

11. Nitric oxide has 11 outer electrons. Among these, one unpaired electron occupies

(a) an antibonding π_{2p} orbital (b) an antibonding π_{2s}^* orbital
(c) An antibonding π_{2p}^* orbital (d) a bonding π_{2p} orbital

12. The resonance structure of NO is represented by

(a)  (b) 

(c)  (d) 

13. The NO molecule

(a) often acts as a one-electron donor, in contrast to most ligands which donate two electrons
(b) often acts as a two-electron donor as is true for most ligands
(c) often acts as a three-electron donor, in contrast to most ligands which donate two electrons
(d) does not act as a donor

14. N_2O_3 is

(a) an acidic oxide, and the anhydride of HNO_2

(b) an acidic oxide, and the anhydride of $H_2N_2O_2$

(c) a neutral oxide, and the anhydride of HNO_3

(d) a basic oxide, and the anhydride of HNO_2

15. N_2O_3 can be obtained by cooling (below –30°C) an equimolecular mixture of

(a) N_2O_5 and NO (b) NO and NO_2

(c) N_2 and O_3 (d) NO_2 and O_3

16. Dinitrogen tetroxide (N_2O_4) has

(a) two unpaired electrons and is paramagnetic

(b) two unpaired electrons and is diamagnetic

(c) one unpaired electron and is paramagnetic

(d) no unpaired electron and is diamagnetic

17. Which of the following oxides of nitrogen is a mixed anhydride of two acids?

(a) N_2O (b) NO

(c) N_2O_4 (d) NO_3

18. Which of the following molecules does not undergo self-ionization?

(a) N_2O_4 (l) (b) H_2O(l)

(c) NH_3(l) (d) HNO_3(l)

19. Which of the following statements is correct for the N_2O_4 molecule?

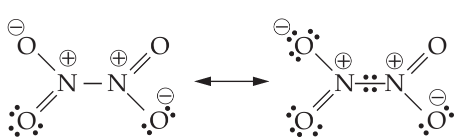
(a) The N—N bond is very short and strong.

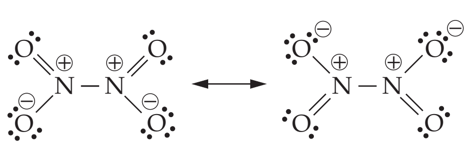
(b) The N—N bond is very short and weak.

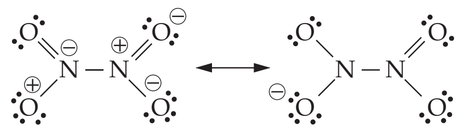
(c) It is a neutral oxide.

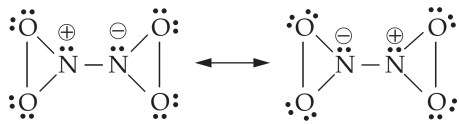
(d) It is a paramagnetic molecule.

20. Which of the following structures correctly represents the resonance hybrid of N_2O_4?

(a) 

(b) 

(c) 

(d) 

21. During the formation of the N_2O_4 dimer from two molecules of NO_2, the odd electrons, one in each of the nitrogen atoms of the NO_2 molecules, get paired to form a

(a) weak N—N bond, two N—O bonds become equivalent and the other two N—O bonds become nonequivalent

(b) weak N—N bond and all the four N—O bonds become equivalent

(c) weak N—N bond and all the four N—O bonds become nonequivalent

(d) strong N—N bond and all the four N—O bonds become equivalent

22. Dinitrogen pentoxide (N_2O_5), a colourless solid, is prepared by

(a) heating NH_4NO_2 with an excess of oxygen

(b) dehydrating HNO_3 with CaO

(c) dehydrating HNO_3 with P_4O_{10}

(d) heating a mixture of HNO_2 and $Ca(NO_3)_2$

23. Arrange NO_2^+, NO_2 and NO_2^- in order of increasing N—O bond length.

(a) $NO_2^+ < NO_2 < NO_2^-$ (b) $NO_2^- < NO_2^+ < NO_2$

(c) $NO_2 < NO_2^- < NO_2^+$ (d) $NO_2^+ = NO_2^- < NO_2$

24. Which among the following is the least basic?

(a) NCl_3 (b) NBr_3

(c) NI_3 (d) NF_3

25. Which among the following is a deliquescent ionic solid?

(a) BrF_5 (b) S_4N_4

(c) N_2O_5 (d) NO

26. Which of the following statements is correct?

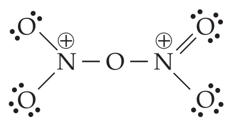
(a) NO_2^- is linear.

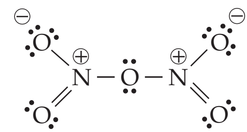
(b) NO_2^+ is pyramidal.

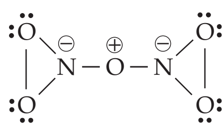
(c) N_2O_5 is represented as $NO_2^+\,NO_3^-$.

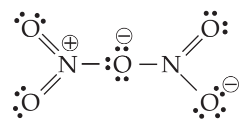
(d) N_2O_5 reacts with concentrated H_2SO_4 to produce $NO_2^+HSO_4^-$.

27. Which of the following structures is the correct representation of N_2O_5 in the gaseous phase?

(a) 

(b) 

(c) 

(d) 

28. An aqueous solution of nitrous acid (HNO_2), free of salts, can be obtained from the reaction

(a) $Ba(NO_2)_2 + H_2SO_4 \longrightarrow$

(b) $NaNO_2 + H_2SO_4 \xrightarrow{\text{cold}}$

(c) $NH_4NO_2 + H_2SO_4 \xrightarrow{\Delta}$

(d) $KNO_3 + HNO_3 \longrightarrow$

29. In which of the following reactions does HNO_2 act as an oxidizing agent?

(a) $Cr_2O_7^{2-} + H^+ + NO_2^- \longrightarrow Cr^{3+} + NO_3^- + H_2O$

(b) $Cl_2 + HNO_2 \longrightarrow HCl + HNO_3$

(c) $SO_2 + HNO_2 \longrightarrow H_2SO_4 + NO$

(d) $O_3 + H^+ + NO_2^- \longrightarrow NO_3^- + O_2$

30. In which of the following reactions does HNO_2 act as a reducing agent?

(a) $FeSO_4 + H_2SO_4 + HNO_2 \rightarrow Fe_2(SO_4)_3 + NO + H_2O$

(b) $KMnO_4 + H_2SO_4 + HNO_2 \rightarrow K_2SO_4 + MnSO_4 + HNO_3 + H_2O$

(c) $KI + H_2SO_4 + HNO_2 \rightarrow K_2SO_4 + NO + I_2 + H_2O$

(d) $SnCl_2 + HCl + HNO_2 \rightarrow SnCl_4 + NO + H_2O$

31. HNO_2 reacts with secondary amines to produce

(a) diazo salts (b) nitrile

(c) nitrogen (d) nitrosoamines

32. Urea reacts with HNO_2 to produce

(a) CO, N_2 and H_2O
(b) CO_2 and N_2
(c) CO_2, NO and NO_2
(d) CO, N_2O and H_2O

33. In the nitrite ion NO_2^-, the bond orders of the two N—O bonds are

(a) 2.0 and 1.0
(b) both 1.5
(c) 2.5 and 1.5
(d) both 2.5

34. In dinitrogen pentoxide, the central NON bond angle is close to

(a) 180°
(b) 120°
(c) 90°
(d) 134°

35. N_2O_5 reacts with iodine to produce

(a) I_2O_6
(b) IO_3
(c) I_2O_5
(d) $I_2O_5 + N_2O$

36. The first ionization energy of NO is less than that of

(a) N_2
(b) O_2
(c) Xe
(d) all of these

37. In the nitrous oxide molecule, the N—N as well as the N—O bond have

(a) some double bond character
(b) some triple bond character
(c) a d orbital involved in bonding
(d) none of these

38. Which of the following pairs has a plane-triangle structure?

(a) NO_3^- and NH_3
(b) NO_2^+ and BF_3
(c) NO_3^- and CO_3^{2-}
(d) NO_3^- and XeO_3

39. In which of the following reactions will HNO_3 not act as an oxidizing agent?

(a) $HNO_3 + H_2SO_4 \longrightarrow$
(b) $HNO_3 + FeSO_4 + H_2SO_4 \longrightarrow$
(c) $KI + HNO_3 \longrightarrow$
(d) $Au + HNO_3 \longrightarrow$

40. Which of the following metals are passive to treatment with concentrated HNO_3?

(a) Ni
(b) Cr
(c) Co
(d) All of these

41. The reduction of NO_3^- in an alkaline medium with zinc gives

(a) N_2O_4
(b) N_2O_5
(c) NH_3
(d) NH_4^+

42. Which of the following factors is responsible for the passivity of a metal?
(a) The formation of a self-protecting coating of the basic carbonate of the metal over its surface,
(b) The formation of a thin layer of the oxide of the metal on its surface, preventing the action of the reagent,
(c) The formation of a thin layer of the nitrate of the metal on its surface, preventing the action of the reagent
(d) None of these

43. The reaction of HNO_3 with P_4O_{10} gives
(a) N_2O_5 (b) NO_2
(c) N_2O_4 (d) N_2O

44. The nitrogen fixation of atmospheric nitrogen utilises the
(a) Fischer–Tropsch process (b) Frasch process
(c) Haber process (d) Solvay process

45. The catalytic oxidation of NH_3 yields
(a) N_2O_5 (b) NO
(c) NO_2 (d) N_2

46. A good yield is obtained when HNO_3 is manufactured by the
(a) Ostwald process (b) Haber process
(c) Birkeland–Eyde process (d) Hall process

47. Concentrated HNO_3 acts as an oxidizing agent with
(a) P_4 (b) NaBr (c) Sn (d) all of these

48. The reaction of zinc with very dilute HNO_3 leads to the formation of
(a) N_2O_5 (b) N_2O
(c) NH_4NO_3 (d) NH_4NO_2

49. Pure HNO_3 is a colourless liquid, but on exposure to light it turns slightly brown. This is due to the slight decomposition of HNO_3 into
(a) NO and NO_2 (b) NO_2 and O_2
(c) NO and O_2 (d) N_2O_5 and O_2

50. The active species in the nitration of an aromatic organic compound is
(a) NO_2 (b) NO_3^-
(c) NO_2^+ (d) NO_2^-

51. Gold and platinum react with aqua regia to form soluble complexes. The complexes with oxidation number +3 and +4, respectively, are
(a) $H_2[AuCl_5]$ and $H_2[PtCl_6]$ (b) $H[AuCl_4]$ and $H_2[PtCl_6]$
(c) $H[AuCl_4]$ and $H_4[PtCl_8]$ (d) $H_3[AuCl_6]$ and $H[PtCl_5]$

52. Which of the following nitrates does not give O_2 on heating?

(a) $Zn(NO_3)_2$ (b) KNO_3

(c) $Pb(NO_3)_2$ (d) NH_4NO_2

53. On heating, which of the following nitrates gives two gaseous products?

(a) NH_4NO_3 (b) NH_4NO_2

(c) $Cu(NO_3)_2$ (d) $NaNO_3$

54. The NO_2^- ion is determined volumetrically by using

(a) KI (b) $KClO_3$

(c) $Na_2S_2O_3$ (d) $CuSO_4$

55. Which of the following species is planar?

(a) NO_3^- (b) N_2O_4

(c) N_2O_5 (d) All of these

56. The nitrite ion is angular, and in it

(a) the nitrogen atom has three sp^2 orbitals and contains a lone pair of electrons

(b) the nitrogen atom has three sp^2 orbitals, and contain an unpaired electron

(c) the nitrogen atom has three sp orbitals, and contains a lone pair of electrons

(d) the nitrogen atom has three sp^3 orbitals, and contains a lone pair of electrons

57. Each of the N—O bonds in the NO_3^- ion has a bond order of

(a) 0.33 (b) 1.33

(c) 1.50 (d) 1.00

58. Upon reacting with tin, hot concentrated HNO_3 produces

(a) $Sn(NO_3)_2$ (b) H_2SnO_3

(c) SnO_2 (d) $Sn(NO_3)_4$

59. Calcium reacts with nitrogen gas to produce a white ionic solid, which on hydrolysis gives the gas (or gases)

(a) NH_3 (b) N_2O

(c) NO_2 (d) NH_3 and NO

60. Which of the following catalysts is commonly employed in the manufacture of ammonia by the Haber process?

(a) Finely divided platinum together with a nickel promoter

(b) Finely divided nickel together with a platinum promoter

(c) Finely divided iron together with a molybdenum promoter

(d) Finely divided palladium together with a zinc promoter

61. Which of the following compounds does not produce ammonia on heating?

(a) NH_4Cl (b) $(NH_4)_2SO_4$

(c) $NaNH_4HPO_4 \cdot 4H_2O$ (d) NH_4NO_2

62. For the catalytic oxidation of ammonia into nitric oxide by the oxygen of air,

(a) heat is required to initiate the reaction, and thereafter the temperature has to be maintained at the requisite level for the reaction

(b) no heat is required to initiate the reaction as the reaction is exothermic

(c) efficient cooling is required all along the process

(d) no heat is required to carry out the process

63. Which of the following gases can be liquefied easily?

(a) He (b) NH_3

(c) H_2 (d) H_2O

64. A solution of sodium in liquid ammonia is blue due to the presence of

(a) solvated electrons and solvated sodium ions

(b) solvated amide ions

(c) solvated azide ions

(d) solvated sodium atoms

65. Ammonia gas is dried over

(a) P_4O_{10} (b) CaO

(c) H_2SO_4 (d) $CaCl_2$

66. Which of the following cations does not form a complex with ammonia?

(a) Co^{3+} (b) Ni^{2+}

(c) Pb^{2+} (d) Zn^{2+}

67. Which of the following compounds gives a black precipitate on reacting with an ammonia solution?

(a) $ZnSO_4$ (b) Hg_2Cl_2 (c) $FeCl_3$ (d) $NiSO_4$

68. Hydrazine is manufactured by the

(a) Raschig process (b) Deacon process

(c) Dow process (d) Diazo process

69. Ammonia reacts with NaOCl to produce in NaOH

(a) N_2H_4, NaCl and N_2O (b) NO_2, HN_3 and NH_2Cl

(c) N_2H_4 and NH_2Cl (d) N_2H_4 and NaCl

70. Sodium reacts with liquid ammonia to produce

(a) $NaNH_2 + N_2 + H_2$ (b) $NaNH_2 + H_2$

(c) $NaNH_2 + N_2H_4$ (d) $NaNH_2 + N_2$

71. By reacting with which of the following reagents does ammonia produce a brown precipitate?

(a) Schiff's reagent (b) Fehling's solution

(c) Grignard reagent (d) Nessler's reagent

72. Sodium azide is prepared by the reaction between

(a) N_2H_4 and H_2 (b) NH_3 and NaOCl

(c) N_2O and $NaNH_2$ (d) NH_2OH and N_2H_4

73. Hydroxylamine is prepared by reducing nitrites with

(a) $C_6H_5NO_2$

(b) SO_2 in the presence of $NaHSO_3$

(c) SO_2 in the presence of Na_2SO_4

(d) $Na_2S_2O_3$

74. Among the following, which is the weakest base?

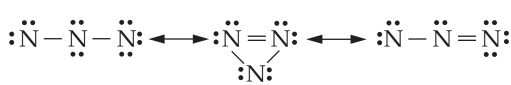
(a) NH_3 (b) N_2H_4 (c) NH_2OH (d) $C_2H_5NH_2$

75. The resonance structure of the azide ion is

(a)


(b)


(c)


(d)


76. The azide ion is

(a) asymmetrical and bent (b) isoelectronic with O_3

(c) symmetrical and linear (d) pyramidal

77. The azide ion has

(a) 20 outer electrons and is isoelectronic with Br_2O

(b) 18 outer electrons and is isoelectronic with NO_2^-

(c) 16 outer electrons and is isoelectronic with CO_2

(d) 14 outer electrons and is isoelectronic with H_2O_2

78. On combustion, hydrazine gives

(a) N_2 (b) N_2O_5

(c) N_2O_4 (d) NH_2OH

79. Which of the following statements is correct for HN_3 (hydrogen azide)?

(a) The addition of the extra electron from the hydrogen atom means that one electron must occupy an antibonding molecular orbital, and hence the lengths of the two N—N bonds are different.

(b) It uses eight electrons for sigma bonding.

(c) It uses six electrons for pi bonding.

(d) The bond orders of the two nitrogen-nitrogen bonds are 2.5 and 3.0.

80. Which of the following polymers are obtained by heating ε-caprolactum?

(a) Nylon-6 (b) Nylon-66

(c) Polyvinyl chloride (d) Teflon

81. Which of the following molecules is stable, not hydrolysed by water, and has little tendency to act as a donor?

(a) NBr_3 (b) NCl_3

(c) NF_3 (d) NBr_3

82. NCl_3 is hydrolysed by water to produce

(a) NH_2NH_2 and HCl (b) NH_2Cl and HOCl

(c) $NH_4^+OH^-$ and HOCl (d) NH_2OH and HOCl

83. Nitrogen is unable to form pentahalides because of the

(a) presence of 2s and 2p orbitals

(b) absence of 3d orbitals

(c) absence of 3p and 3d orbitals

(d) absence of 3s, 3p and 3d orbitals

84. Which of the following molecules is planar around nitrogen?

(a) $N(SiH_3)_3$ (b) $Si(NH_3)_3$ (c) $P(NH_3)_3$ (d) $C_6H_5N(CH_3)_2$

85. Among the following, which is the fertilizer that has the highest percentage of nitrogen and is easily assimilated in soil?

(a) $CaCN_2$ (b) $(NH_4)_2SO_4$

(c) KNO_3 (d) Urea

86. Superphosphate is a mixture of $3Ca(H_2PO_4)_2$ and $7CaSO_4$, and is prepared by the reaction between

(a) $Ca_3(PO_4)_2{\cdot}CaF_2$ and H_3PO_4 (b) $Ca_3(PO_4)_2{\cdot}CaCl_2$ and H_2SO_4

(c) $Ca_3(PO_4)_2{\cdot}CaF_2$ and HCl (d) $Ca_3(PO_4)_2{\cdot}CaCl_2$ and $CaSO_4$

87. Triple superphosphate is represented by the formula $4Ca(H_2PO_4)_2$, and is produced by the reaction between

(a) $3Ca(H_2PO_4)_2$ and $NaHF_2$
(b) $4Ca_3(PO_4)_2$ and $CaCl_2$
(c) $Ca_3(PO_4)_2{\cdot}CaF_2$ and $6H_3PO_4$
(d) $AlPO_4$ and CaH_2PO_4

88. White phosphorus is more reactive than the nitrogen molecule because the

(a) electronegativity of phosphorus is low.
(b) ionization energy of phosphorus is greater than that of N_2
(c) P—P bond in phosphorus is weaker than the N≡N bond in nitrogen
(d) P—P—P bond angle is 120° whereas N_2 is linear

89. The most reactive and least reactive forms of phosphorus are respectively

(a) red and white phosphorus
(b) white and black phosphorus
(c) scarlet and red phosphorus
(d) white and red phosphorus

90. In which of the following properties does white phosphorus resemble red phosphorus?

(a) Burning in the presence of air
(b) Solubility in an organic solvent
(c) Fluorescence and phosphorescence
(d) Reaction with concentrated NaOH to produce PH_3

91. White phosphorus reacts with calcium to form a certain compound which, on hydrolysis, produces

(a) PH_3 (b) P_2H_4 (c) P_4O_6 (d) P_4O_{10}

92. On hydrolysis, PCl_5 would produce

(a) HPO_3 (b) H_3PO_4 (c) H_3PO_3 (d) $H_4P_2O_7$

93. In the solid state, PCl_5 exists as

(a) $[PCl_4]^-$ and $[PCl_6]^+$ ions
(b) covalent PCl_5 molecules only
(c) $[PCl_4]^+$ and $[PCl_6]^-$ ions
(d) $[PCl_3]^{2-}$ and $[PCl_5]^{2+}$ ions

94. Which of the following pentahalides is highly reactive and unstable, and is not possible to isolate?

(a) PCl_5
(b) $SbCl_5$
(c) $AsCl_5$
(d) PBr_5

95. PCl_5 reacts with NH_4Cl to form
(a) phosphonium chloride and NH_3
(b) phosphonitrile chloride polymers $(NPCl_2)_n$
(c) phosphorus triammine and Cl_2
(d) phosphorus pentammine and N_2

96. In P_4O_{10}, the
(a) second bond in P═O is formed by pπ-dπ back bonding
(b) P═O bond is formed by pπ-pπ bonding
(c) P═O bond is formed by dπ-dπ bonding
(d) P═O bond is formed by dπ-dπ-3σ back bonding

97. Phosphorus is obtained by the reduction of phosphate rock using
(a) coke and silica at high temperature
(b) Al at high temperature
(c) Fe_2O_3 and coke at high temperature.
(d) silica at high temperature

98. The basic character of NH_3, PH_3, AsH_3 and SbH_3 decreases in the order
(a) $SbH_3 > PH_3 > AsH_3 > NH_3$
(b) $NH_3 > PH_3 > AsH_3 > SbH_3$
(c) $NH_3 > SbH_3 > PH_3 > AsH_3$
(d) $AsH_3 > PH_3 > SbH_3 > NH_3$

99. In the reaction

$$P_4 + 3KOH + 3H_2O \longrightarrow 3KH_2PO_2 + PH_3,$$

phosphorus is
(a) only oxidized
(b) only reduced
(c) oxidized as well as reduced
(d) neither oxidized nor reduced

100. The number of short P—O bonds in P_4O_{10} is
(a) one (b) two
(c) three (d) four

101. Arrange ZnO, MgO, P_4O_6 and SO_3 in order of increasing acidic strength.
(a) $MgO < ZnO < SO_3 < P_4O_6$ (b) $MgO < ZnO < P_4O_6 < SO_3$
(c) $ZnO < MgO < SO_3 < P_4O_6$ (d) $ZnO < MgO < P_4O_6 < SO_3$

102. Which of the following oxoacids of phosphorus are mono-, di- and triprotic acids respectively?
(a) HPO_3, $H_4P_2O_7$, H_3PO_3 (b) HPO_3, $H_6P_4O_{13}$, H_3PO_4
(c) H_3PO_2, H_3PO_3, H_3PO_4 (d) HPO_3, $H_5P_3O_{11}$, H_3PO_4

103. Among the following molecules, which contains the maximum number of P—H bonds?

(a) $H_4P_2O_7$ (b) H_3PO_2 (c) H_3PO_3 (d) H_3PO_4

104. The number of P—O—P bonds in cyclic metaphosphoric acid is

(a) zero (b) two (c) three (d) four

105. Which of the following oxoacids of phosphorus is a reducing agent and a monobasic acid as well?

(a) H_3PO_2 (b) HPO_3 (c) H_3PO_3 (d) $H_4P_2O_5$

106. Which of the following is a cyclic phosphate?

(a) $Na_5P_3O_{10}$ (b) $Na_6P_4O_{13}$

(c) $Na_7P_5O_{16}$ (d) $Na_5P_5O_{15}$

107. The phosphate group can be estimated quantitatively by precipitating

(a) $Mg_2(NH_4)_2PO_4$ (b) $Mg(NH_4)PO_4$

(c) $Mg_3(PO_4)_2$ (d) $Mg(NH_4)HPO_4$

108. Which of the following oxoacids of phosphorus is a reducing agent as well as a dibasic acid?

(a) H_3PO_3 (b) HPO_3

(c) H_3PO_2 (d) H_3PO_4

109. Which of the following oxacids of phosphorus contains a P—P bond?

(a) Hypophosphorus acid (b) Tripolyphosphoric acid

(c) Pyrophosphoric acid (d) Hypophosphoric acid

110. Which of the following allotropic forms of phosphorus is the most stable, least reactive, has a graphite-like structure, and is a good conductor of electricity?

(a) White phosphorus (b) Red phosphorus

(c) Black phosphorus (d) Scarlet phosphorus

• *Type 2* •

Choose the correct options. More than one option is correct.

111. Nitrogen is prepared by heating

(a) a mixture of CuO and NH_3

(b) microcosmic salt, $NaNH_4HPO_4 \cdot 4H_2O$

(c) barium azide

(d) a mixture of NH_4Cl and $NaNO_3$

112. Which of the following statements are correct for the nitrogen molecule?
(a) The bond order is 2.0.
(b) It is a good ligand.
(c) It is used in the Serpeck process.
(d) It easily reacts with magnesium even at room temperature.

113. Nitrous oxide is prepared by
(a) heating a mixture of NH_4Cl and $NaNO_3$
(b) heating a mixture of NH_4Cl and $NaNO_2$
(c) the hydrolysis of Mg_3N_2
(d) heating a mixture of nitric oxide and sulphur dioxide

114. Which of the following statements are correct?
(a) The addition of an electron to NO forms stable NO^-.
(b) The removal of an electron from NO forms stable NO^+.
(c) The bond length in NO is greater than that in the NO^+ ion.
(d) The bond order of NO^+ is 3.0.

115. Which of the following statements are correct?
(a) The ionization energy of NO is greater than that of N_2.
(b) The second ionization energy of nitrogen is less than that of oxygen.
(c) The odd electron in NO is more easily removed from the antibonding π^* molecular orbital to form the NO^+ ion.
(d) The electronegativity of nitrogen is greater than that of oxygen.

116. The molecule NO_2
(a) is diamagnetic
(b) dimerizes to N_2O_4 under suitable conditions
(c) is paramagnetic
(d) can be converted into liquid NO_2

117. Which of the following are not explosives?
(a) Calcium cyanamide
(b) Cellulose nitrate
(c) Cellulose
(d) Nitrogen trifluoride

118. Ammonia acts as a reducing agent when treated with
(a) CuO
(b) H_2S
(c) HI
(d) NaOCl

119. Which of the following is used as a nonaqueous solvent?
(a) NH_3
(b) NO_2
(c) SO_2
(d) BrF_3

120. Which of the following are used as ligands in the preparation of coordination compounds?

(a) NH_3 (b) PH_3 (c) $(C_6H_5)_3P$ (d) O_2

121. Hydrazine is a reducing agent when treaed with

(a) I_2 (b) $FeSO_4$ (c) $CuSO_4$ (d) $SnCl_2$

122. Which of the following statements are correct for the P_4 molecule?

(a) The P—P bond distances are equal.

(b) The P—P—P bond angles are 60°.

(c) It reacts with nitrogen to form a phosphorus-nitrogen polymer.

(d) The electron affinity of phosphorus is negative.

123. Which of the following statements are correct for the P_4O_6 molecule?

(a) The four phosphorus atoms are arranged in a tetrahedral form.

(b) The six oxygen atoms are situated along the edges of a tetrahedron.

(c) Each oxygen atom is bonded to two adjacent phosphorus atoms.

(d) The structure of P_4O_6 is derived from that of PCl_3.

124. Which of the following statements are correct for the P_4O_{10} molecule?

(a) The lone pairs on each of the four phosphorus atoms form a coordinate bond with an oxygen atom.

(b) Their orbitals exhibit back bonding.

(c) It is hydrolysed by water, forming $H_4P_2O_7$.

(d) It has no structural similarity with As_4O_{10}.

125. Which of the following oxoacids of phosphorus do not contain a P—P bone?

(a) HPO_3 (b) $H_4P_2O_7$ (c) $H_4P_2O_6$ (d) $H_3P_3O_9$

Answers

1. b	**2.** a	**3.** d	**4.** a	**5.** d
6. c	**7.** d	**8.** a	**9.** a	**10.** b
11. c	**12.** b	**13.** c	**14.** a	**15.** b
16. d	**17.** c	**18.** d	**19.** a	**20.** b
21. b	**22.** c	**23.** a	**24.** d	**25.** c
26. c	**27.** b	**28.** a	**29.** c	**30.** b
31. d	**32.** a	**33.** b	**34.** a	**35.** c
36. d	**37.** b	**38.** c	**39.** a	**40.** d
41. c	**42.** b	**43.** a	**44.** c	**45.** b

46. a	**47.** d	**48.** c	**49.** b	**50.** c
51. b	**52.** d	**53.** c	**54.** a	**55.** d
56. a	**57.** c	**58.** b	**59.** a	**60.** c
61. d	**62.** a	**63.** d	**64.** a	**65.** b
66. c	**67.** b	**68.** a	**69.** d	**70.** b
71. d	**72.** c	**73.** b	**74.** c	**75.** b
76. c	**77.** c	**78.** a	**79.** a	**80.** a
81. c	**82.** c	**83.** b	**84.** a	**85.** d
86. b	**87.** c	**88.** c	**89.** d	**90.** d
91. a	**92.** b	**93.** c	**94.** c	**95.** b
96. a	**97.** a	**98.** b	**99.** c	**100.** d
101. b	**102.** c	**103.** b	**104.** c	**105.** a
106. d	**107.** b	**108.** a	**109.** d	**110.** c
111. a, c	**112.** b, c	**113.** a, d	**114.** b, c, d	**115.** b, c
116. b, c, d	**117.** a, c	**118.** a, d	**119.** a, b, c, d	**120.** a, b, c, d
121. a, c	**122.** a, b	**123.** a, b, c	**124.** a, b	**125.** a, b, d

Hints to More Difficult Problems

3. Larger electronegativity difference between Bi and F

7. The N—N bond has a double-bond character, which shortens the bond length.

8. N_2 as well as CO have a bond order equal to three. See the molecular-orbital energy diagram.

11. See the molecular-orbital energy diagram.

26. N_2O_5 is called nitronium nitrate ($NO_2^+NO_3^-$).

29. The oxidation number of N is reduced from +3 to +2.

30. The oxidation number of N increases from +3 to +5.

31. These are Liebermann nitroso reactions.

39. In option (a) both HNO_3 and H_2SO_4 are oxidizing agents. In option (b), (c) and (d), $FeSO_4$, KI and Au are all reducing agents. So all of them react with HNO_3.

40. All the metals form a self-protecting oxide layer over themselves.

41. $4Zn + NO_3^- + 7(OH^-) \longrightarrow NH_3 + 4ZnO_2^{2-} + 2H_2O$

59. $3Ca + N_2 \longrightarrow Ca_3N_2$
$Ca_3N_2 + 6H_2O \longrightarrow 3Ca(OH)_2 + 2NH_3$

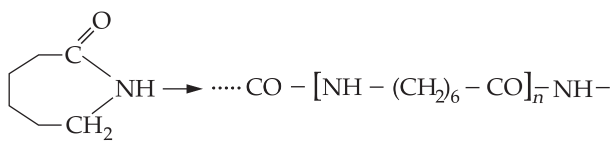
63. The high value of the van der Waals constant *a* facilitates liquefaction of $H_2O(g)$.

65. NH_3 and CaO are both basic. They do not react with each other.

67. $Hg_2Cl_2 + 2NH_3 \longrightarrow \underbrace{Hg(NH_2)Cl + Hg}_{\text{black}} + NH_4Cl$

68. $2NH_3 + NaOCl \xrightarrow[\text{process}]{\text{Raschig}} N_2H_4 + NaCl + H_2O$

80.



∈- caprolactum nylon-6

91. $P_4 + 6Ca \xrightarrow{\text{heat}} 2Ca_3P_2$

$Ca_3P_2 + 6H_2O \longrightarrow 3Ca(OH)_2 + 2PH_3$

97. $2Ca_3(PO_4)_2 + 6SiO_2 + 10C \longrightarrow P_4 + 6CaSiO_3 + 10CO$

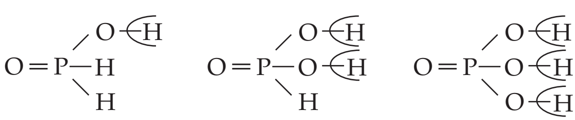
98. The lower the value of pk_b, the greater will be the basic strength.

99. $\overset{0}{P_4} \longrightarrow NaH_2\overset{+1}{P}O_2$ (oxidised)

$P_4 \longrightarrow \overset{-3}{P}H_3$ (reduced)

101. Polarization effect

102.



monoprotic diprotic triprotic

107. $MgCl_2 + Na_2HPO_4 + NH_3 \longrightarrow Mg(NH_4)PO_4 \downarrow + 2NaCl$

112. $:N{\equiv}N:$ (lone pair of electrons $\longrightarrow$ good ligand)

$Al_2O_3 + 3C + N_2 \xrightarrow[> 1100°C]{\text{Serpeck process}} 2AlN + 3CO \uparrow$

116. (b) $2NO_2(g) \rightleftharpoons N_2S_4(g)$ (c) NO_2 contains an unpaired electron
(d) $NO_2(g) \longrightarrow NO_2(l)$ using the process of liquefaction (Joule-Thomson effect)

120. All contain a lone pair of electrons

❑

8

Sulphur

• Type 1 •

Choose the correct option. Only one option is correct.

1. Which of the following oxoacids of sulphur contains sulphur-sulphur double bonds?

(a) $H_2S_2O_8$ (b) $H_2S_2O_7$

(c) $H_2S_2O_3$ (d) $H_2S_2O_6$

2. The best known sulphur-nitrogen compound is

(a) S_2N_4 (b) S_4N_4

(c) S_8N_3 (d) S_3N_8

3. When H_2S gas is passed into aqueous sulphur dioxide,

(a) H_2S is converted into a yellow precipitate of sulphur

(b) SO_2 is converted into a yellow precipitate of sulphur

(c) a clear solution of H_2SO_4 is formed

(d) SO_2 as well as H_2S are converted into a yellow precipitate of sulphur

4. In thiosulphuric acid ($H_2S_2O_3$), the two sulphur atoms have the oxidation states

(a) +2 and –2 (b) +4 and –2

(c) +6 and +2 (d) +4 and +2

5. In the cyclo-S_8 molecule of rhombic sulphur, all the S—S bond lengths and all the S—S—S bond angles are respectively (give approximate values)

(a) 204 pm and 105° (b) 102 pm and 120°

(c) 204 pm and 180° (d) 102 pm and 60°

6. Which of the following allotropic forms of sulphur is the most stable thermodynamically?

(a) Orthorhombic (b) β-monoclinic

(c) γ-monoclinic (d) Plastic sulphur

7. Pure H_2S is prepared by the action of concentrated HCl on

(a) FeS_2 (b) Cu_2S

(c) FeS (d) Sb_2S_3

8. $Fe_2(SO_4)_3$ can be converted into $FeSO_4$ by the action of

(a) H_2SO_4 (b) HNO_3

(c) H_2SO_3 (d) O_3

9. Dehydration of concentrated H_2SO_4 in the presence of P_4O_{10} produces

(a) SO_2 (b) $H_2S_2O_8$

(c) SO_2 and SO_3 (d) SO_3

10. On strong heating, $Fe_2(SO_4)_3$ gives a mixture of

(a) SO_2 and SO_3 (b) Fe_2O_3 and SO_3

(c) FeO and SO_3 (d) Fe_2O_3 and SO_2

11. The number of S—S bonds in the cyclic trimer of sulphur trioxide is

(a) three (b) two

(c) one (d) zero

12. A gas that cannot be collected over water is

(a) N_2 (b) PH_3

(c) O_2 (d) SO_2

13. Which of the following acids is not a peroxo acid?

(a) CF_3CO_3H (b) $H_2S_2O_8$ (c) $H_2S_2O_7$ (d) H_2SO_5

14. Which of the following oxoacids of sulphur contains a sulphur-sulphur single bond?

(a) $H_2S_2O_6$ (b) $H_2S_2O_7$ (c) $H_2S_2O_8$ (d) $H_2S_2O_3$

15. Which of the following reactions does not produce SO_2?

(a) $Ag + H_2SO_4\text{ (conc.)} \xrightarrow{\Delta}$

(b) $CaSO_4 + C \xrightarrow{\Delta}$

(c) $FeS_2 + O_2 \xrightarrow{\Delta}$

(d) $Zn + H_2SO_4\text{ (dil.)} \xrightarrow{\Delta}$

16. KIO_3 reacts with SO_2 in an acidic medium to produce
(a) I_4O_9 (b) I_2 (c) KIO_4 (d) I_2O_5

17. On heating with sulphur, Na_2SO_3 produces
(a) $Na_2S_2O_3$ (b) Na_2S_5
(c) $Na_2S_2O_7$ (d) $Na_2S_4O_6$

18. Which of the following molecules exists as a cyclic trimer in the solid state?
(a) SO_3 (b) O_3
(c) SO_2 (d) S_4N_4

19. In which of the following pairs do both the species have a similar shape?
(a) SO_4^{2-} and SO_3^{2-} (b) SO_2 and NH_3
(c) SO_4^{2-} and $S_2O_3^{2-}$ (d) SO_3 and $S_2O_8^{2-}$

20. Urea reacts with SO_3 in the presence of H_2SO_4 to produce
(a) NH_2SO_3H (sulphamic acid) (b) NH_2OH
(c) $H_2N \cdot CS \cdot NH_2$ (thiourea) (d) $(NH_4)_2SO_4$

21. The structure of the SO_3 molecule in the gaseous phase contains
(a) only σ-bonds between sulphur and oxygen
(b) σ-bonds and a (p-pπ) bond between sulphur and oxygen
(c) σ-bonds and a (p-pπ) bond between sulphur and oxygen
(d) σ bonds, and a (p-pπ) and a (p-dπ) bond between sulphur and oxygen

22. In preparing a standard solution of Mohr's salt,

$$FeSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O,$$

a few millilitres of H_2SO_4 is added to the solution. The added H_2SO_4
(a) prevents the reduction of the salt
(b) prevents the oxidation of the salt
(c) makes the solution homogeneous by converting insoluble $Fe(OH)_2$, formed by hydrolysis, into soluble $FeSO_4$
(d) neutralizes the ammonia formed by hydrolysis

23. $K_4[Fe(CN)_6]$ reacts with concentrated H_2SO_4 to produce
(a) SO_2 (b) CO
(c) $(CN)_2$ (d) $K_3[Fe(CN)_6]$

24. Concentrated H_2SO_4 reacts with PCl_5 to produce
(a) SO_3 (b) H_3PO_4
(c) SO_2Cl_2 (d) $SOCl_2$

25. The structure of thioxyl chloride is

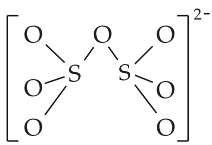
(a) tetrahedral with one corner of the tetrahedron occupied by a lone pair of electrons, the sulphur atom being at the centre.

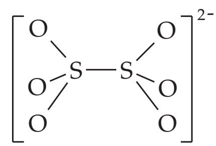
(b) square planar with the sulphur atom at the centre

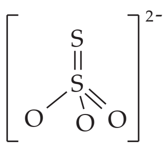
(c) square pyramidal

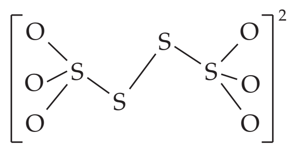
(d) trigonal bipyramidal

26. The structure of the dithionate ion is

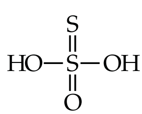
(a) 

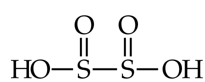
(b) 

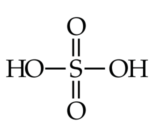
(c) 

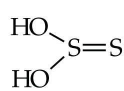
(d) 

27. The structure of thiosulphuric acid is

(a) 

(b) 

(c) 

(d) 

28. The hydrolysis of 1 mol of peroxodisulphuric acid produces

(a) 2 mol of sulphuric acid

(b) 2 mol of peroxomonosulphuric acid

(c) 1 mol each of sulphuric acid and peroxomonosulphuric acid

(d) 1 mol each of sulphuric acid, peroxomonosulphuric acid and hydrogen peroxide

29. The oxidation number of sulphur in the cyclic trimer of sulphur trioxide is

(a) +3 (b) +2 (c) +4 (d) +6

30. When SO_2 gas is passed into an acidified $K_2Cr_2O_7$ solution, the oxidation number of chromium changes from

(a) +3 to +6 (b) +6 to +3

(c) +12 to +3 (d) +6 to –3

31. In the standardization of $Na_2S_2O_3$ using $K_2Cr_2O_7$ by iodometry, the equivalent weight of $K_2Cr_2O_7$ is

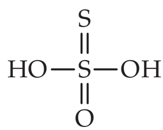
(a) (molecular weight)/2

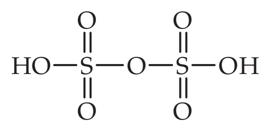
(b) (molecular weight)/6

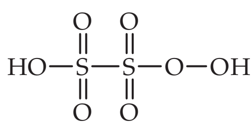
(c) molecular weight)/3

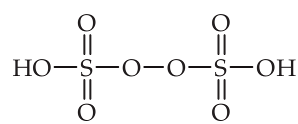
(d) the same as the molecular weight

32. The structure of oleum is

(a) 

(b) 

(c) 

(d) 

33. Which of the following reagents is commonly used for the detection of the sulphide ion?

(a) 1-Nitroso-2-naphthol

(b) Potassium ferricyanide

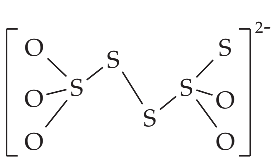
(c) Disodium hydrogen phosphate

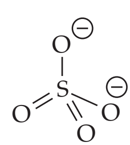
(d) Sodium nitroprusside

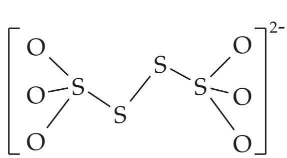
34. Which of the following compounds is required in the "brown ring test" for the nitrate ion in an aqueous medium of concentrated H_2SO_4?

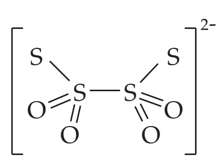
(a) $FeCl_3$ (b) $FeSO_4$ (c) $Fe_2(SO_4)_3$ (d) $Na_2S_2O_3$

35. The structure of the tetrathionate ion is

(a) 

(b) 

(c) 

(d) 

36. In which of the following oxoacids of sulphur are the two sulphur atoms not in the same oxidation state?

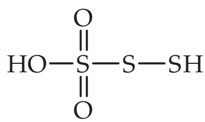
(a) $H_2S_2O_8$ (b) $H_2S_2O_3$ (c) $H_2S_2O_6$ (d) $H_2S_2O_7$

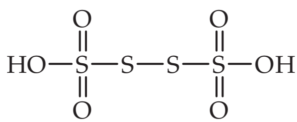
37. Which of the following acids is known as dithionic acid?

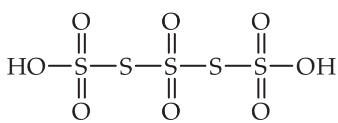
(a) $H_2S_2O_6$ (b) $H_2S_2O_7$

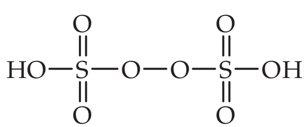
(c) $H_2S_3O_7$ (d) $H_2S_4O_6$

38. The structure of peroxodisulphuric acid is

(a) 

(b) 

(c) 

(d) 

39. Which of the following reactions does not occur?

(a) $H_2SO_4 + HNO_3 \longrightarrow HSO_4^- + NO_2^+ + H_3O^+$

(b) $KIO_3 + SO_2 + H_2O \longrightarrow I_2 + KHSO_4 + H_2SO_4$

(c) $NaHSO_3 + Na_2CO_3 \longrightarrow Na_2SO_4 + H_2O + CO_2$

(d) $2SO_2 \longrightarrow SO^{2+} + SO_3^{2-}$

40. Which of the following statements is correct?

(a) SF_6 does not react with water.

(b) OF_6 is d^2sp^3-hybridized.

(c) $S_2O_3^{2-}$ is a linear ion.

(d) There is no π-bonding in SO_4^{2-}.

41. At high temperature, $CaSO_4$ reacts with carbon to produce a mixture of

(a) CO_2 and SO_2 (b) CO_2, SO_3 and CaO

(c) CO_2, SO_2 and CaS (d) CaO, SO_2 and CO_2

42. $Ca(OH)_2$ reacts with SO_2 to produce

(a) $Ca(HSO_3)_2$ (b) $CaSO_3$

(c) CaS (d) CaO

43. Which of the following oxides have acidic properties?

(a) N_2O (b) CS_2

(c) NO (d) SO_2

44. Elements of Group 16 (except polonium) are called chalcogens because

(a) these elements, particularly sulphur and oxygen, are present in many metallic ores, mainly as oxides and sulphides

(b) a large number of acids contain these elements, particularly sulphur and oxygen

(c) these elements mainly form anions

(d) these elements exist in different allotropic forms

45. The stability of the hydrides of oxygen, sulphur, selenium and tellurium decreases in the order

(a) $H_2Te > H_2Se > H_2S > H_2O$

(b) $H_2O > H_2S > H_2Se > H_2Te$

(c) $H_2S > H_2O > H_2Se > H_2Te$

(d) $H_2O \approx H_2S < H_2Te < H_2Se$

46. Which of the following gases dissolves in liquid SO_2?

(a) He (b) H_2S

(c) SO_3 (d) CO

47. On strong heating, aqueous sodium bisulphite produces

(a) Na_2SO_4 (b) $Na_2S_2O_8$

(c) $NaHSO_4$ (d) $Na_2S_2O_5$

48. Sodium pyrosulphate, $Na_2S_2O_7$, can be made by heating

(a) $NaHSO_4$ strongly

(b) $NaHSO_3$ strongly

(c) a mixture of $Na_2S_2O_3$ and SO_2

(d) a mixture of Na_2SO_3 and excess of sulphur

49. In H_2O, the bond angle H—O—H is 104°28′ but in H_2S, H_2Se and H_2Te the bond angles are pretty close to 90°. This suggests that

(a) oxygen uses sp^2-hybrid orbitals while S, Se and Te use sp^3-hybrid orbitals for bonding with the hydrogen atoms

(b) oxygen uses sp^3-hybrid orbitals to bond with the two hydrogen atoms while S, Se and Te use almost pure p orbitals

(c) oxygen uses sp^3-hybrid orbitals while S, Se and Te utilize d orbitals for bonding with the hydrogen atoms

(d) all the atoms use pure p orbitals to bond with the hydrogen atoms

50. H_2S is far more volatile than water because

(a) the hydrogen atoms are strongly bonded to sulphur

(b) H_2S forms intramolecular hydrogen bonds whereas H_2O forms intermolecular hydrogen bonds

(c) the oxygen atom is more electronegative than the sulphur atom, and hence H_2O forms intermolecular hydrogen bonds

(d) H_2S forms intermolecular hydrogen bonds whereas H_2O forms intramolecular hydrogen bonds

51. H_2S is less stable than water because

(a) H_2O molecules form hydrogen bonds but H_2S molecules do not

(b) the bonding orbitals of sulphur are larger and more diffuse than those of oxygen, and hence their overlap with the 1s orbitals of the hydrogen atoms is less effective

(c) the bonding orbitals of sulphur are smaller and less diffuse than those of oxygen, and hence their overlap with the 1s orbitals of the hydrogen atom is less effective

(d) the bonding orbitals of sulphur are smaller and more diffuse than those of oxygen, resulting in a less effective overlap with the 1s orbitals of the hydrogen atoms

• *Type 2* •

Choose the correct options. More than one option is correct.

52. Which of the following are correctly matched?

(a) Orpiment $\longrightarrow$ As_2S_3

(b) Realgar $\longrightarrow$ As_4S_4

(c) Extraction of sulphur $\longrightarrow$ Frasch process

(d) Extraction of $SO_2(g)$ $\longrightarrow$ Raschig process

53. SO_2 gas may be produced by

(a) burning S in air (b) roasting ZnS

(c) heating $Fe_2(SO_4)_3$ (d) hydrolyzing Na_2SO_4

54. Which of the following may act as an oxidizing as well as a reducing agent?

(a) H_2S (b) H_2SO_4 (c) SO_2 (d) Na_2SO_3

55. Which of the following may form acid salts as well as normal salts?

(a) $NaHSO_4$ (b) H_2S (c) H_2SO_4 (d) $NaHSO_3$

56. In which of the following reactions does concentrated H_2SO_4 act as an oxidizing agent?

(a) $FeSO_4 + H_2SO_4 \longrightarrow$
(b) $ZnO + H_2SO_4 \longrightarrow$
(c) $KBr + H_2SO_4 \longrightarrow$
(d) $NaCl + H_2SO_4 \longrightarrow$

57. Which of the following oxoacids of sulphur contain a peroxo-link?

(a) $H_2S_2O_3$
(b) H_2SO_5
(c) $H_2S_2O_6$
(d) $H_2S_2O_8$

58. Which of the following species have (zero) dipole moment?

(a) SO_2
(b) CS_2
(c) SO_4^{2-}
(d) H_2SO_3

59. Which of the following allotropes of sulphur exist as S_8 molecules with a puckered-ring structure assuming a crown conformation?

(a) γ-Monoclinic
(b) β-Monoclinic
(c) α-Rhombic
(d) γ-Rhombic

60. Which of the following statements are correct for the SO_4^{2-} ion?

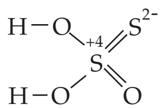
(a) It is tetrahedral.
(b) All the S—O bond lengths are equal, and shorter than expected.
(c) It contains four σ-bonds between the S and the O atoms, two π-bonds delocalized over the S and the four O atoms, and all the S—O bonds have a bond order of 1.5.
(d) It is square planar.

Answers

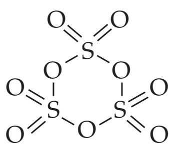
1. c	**2.** b	**3.** d	**4.** 6	**5.** a
6. a	**7.** d	**8.** c	**9.** d	**10.** b
11. d	**12.** d	**13.** c	**14.** a	**15.** d
16. b	**17.** a	**18.** a	**19.** c	**20.** a
21. d	**22.** c	**23.** b	**24.** c	**25.** a
26. b	**27.** c	**28.** c	**29.** d	**30.** b
31. b	**32.** b	**33.** d	**34.** b	**35.** c
36. b	**37.** a	**38.** d	**39.** c	**40.** a
41. c	**42.** b	**43.** d	**44.** a	**45.** b
46. c	**47.** d	**48.** a	**49.** b	**50.** c
51. b	**52.** a, b, c	**53.** a, b	**54.** c, d	**55.** b, c
56. a, c	**57.** b, d	**58.** b, c	**59.** a, b, c	**60.** a, b, c

Hints to More Difficult Problems

4.



11.



The cyclic trimer of SO_3 does not contain an S—S bond.

12. SO_2 reacts with water in the following manner.

$$SO_2 + 2H_2O \longrightarrow SO_4^{2-} + 4H^+ + 2e$$

16.

$$2IO_3^- + 12H^+ + 10e \longrightarrow I_2 + 6H_2O$$
$$SO_2 + 2H_2O \longrightarrow SO_4^{2-} + 4H^+ + 2e \times 5$$
$$2IO_3^- + 5SO_2 + 4H_2O \longrightarrow I_2 + 5SO_4^{2-} + 8H^+$$

28. $H_2S_2O_8 + H_2O \longrightarrow H_2SO_4 + H_2SO_5$

29. The oxidation number of S in SO_3 is +6. This is true for the trimer also.

30. $Cr_2O_7^{2-} + H^+ + 3SO_2 \longrightarrow 2Cr^{3+} + 7H_2O + 3SO_4^{2-}$. The oxidation number of Cr in $Cr_2O_7^{2-}$ is +6 and that in Cr^{3+} is +3.

31. $Cr_2O_7^{2-} + 14H^+ + 6e \longrightarrow 2Cr^{3+} + 7H_2O$

Eq wt $(K_2Cr_2O_7) = \dfrac{\text{mol. wt}}{6}$ (six electrons are gained in the process)

33. The sulphide ion, S^{2-}, reacts with sodium nitroprusside to give a dark red complex.

$$S^{2-} + Na_2[Fe(CN)_5NO] \longrightarrow \underset{\text{dark red complex}}{Na_2[Fe(CN)_5NOS]} + 2e$$

36. See the answer to Q. 4.

40. Because of the high S—F bond strength, coordination saturation is stable. The lack of polarity of the molecule is also a factor.

43. $SO_2 + 2H_2O \longrightarrow H_2SO_4 + 2H^+ + 2e$

55. H_2S as well as H_2SO_4 form two series of salts. For example, Na_2S and $NaHSO_4$, Na_2SO_4.

57. $\mathrm{H}-\underbrace{\ddot{\underset{\cdot\cdot}{\mathrm{O}}}-\ddot{\underset{\cdot\cdot}{\mathrm{O}}}}_{\text{Peroxide link}}-\mathrm{SO_3H}$ (H_2SO_5)

$\mathrm{HO_3S}-\underbrace{\ddot{\underset{\cdot\cdot}{\mathrm{O}}}-\ddot{\underset{\cdot\cdot}{\mathrm{O}}}}_{\text{Peroxide link}}-\mathrm{SO_3H}$ $(H_2S_2O_8)$

❑

9

The Halogens

• *Type 1* •

Choose the correct option. Only one option is correct.

1. Among the following, the properties of which pair of halogens are more similar than those of the other pairs?

(a) Fluorine and bromine
(b) Fluorine and chlorine
(c) Chlorine and bromine
(d) Fluorine and astatine

2. The colour of halogens progressively deepens from fluorine to iodine because

(a) halogens of higher atomic number absorb light of longer wavelength since the difference in energy between the ground state and excited state decreases as the atomic number increases.

(b) fluorescence and phosphorescence become more intense as the atomic numbers of halogen increases

(c) the standard electrode potential increases from I_2 to F_2.

(d) halogens of higher atomic number absorb light of shorter wavelength since the difference in energy between the ground state and excited state increases as the atomic number increases.

3. Which of the following has been arranged in order of increasing bond energy?

(a) $Cl_2 < I_2 < Br_2 < F_2$
(b) $F_2 < I_2 < Cl_2 < Br_2$
(c) $F_2 < Br_2 < Cl_2 < I_2$
(d) $I_2 < F_2 < Br_2 < Cl_2$

4. Which of the following pairs of halogens have approximately identical bond energy?

(a) F_2 and Br_2
(b) F_2 and I_2
(c) F_2 and Cl_2
(d) Cl_2 and I_2

5. The reaction

$$3ClO^-(aq) \longrightarrow ClO_3^-(aq) + 2Cl^-(aq)$$

is an example of

(a) oxidation (b) reduction
(c) disproportionation (d) decomposition

6. The F—F bond is weak because

(a) the repulsion between the nonbonding pairs of electrons of two fluorine atoms is large
(b) the ionization energy of the fluorine atom is very low
(c) the length of the F—F bond much larger than the bond lengths in other halogen molecules
(d) the F—F bond distance is small and hence the internuclear repulsion between the two F atoms is very low

7. Fluorine is prepared by the electrolysis of

(a) molten NaF
(b) a molten mixture of $Ca_3(PO_4)_2 \cdot CaF_2$ and cryolite
(c) a solution of KHF_2 in HF
(d) a solution of KHF_2 in KF

8. Fluorine may be prepared by the electrolysis of a molten mixture of KHF_2 and KF. The anode is made of

(a) copper (b) iron
(c) graphite (d) ungraphitized carbon

9. Fluorine shows only one oxidation state (–1) because it has

(a) a high electronegativity
(b) no d orbital available for bonding
(c) a small covalent radius
(d) a low bond energy

10. Fluorine reacts with water to produce

(a) HF and H_2O_2 (b) HF, O_2 and F_2O_2
(c) F^-, O_2 and H^+ (d) F_2O and F_2O_2

11. Fluorine reacts with H_2S to produce

(a) SF_2 (b) SF_4
(c) S and HF (d) SF_6

12. Fluorine reacts with dilute NaOH and concentrated NaOH to respectively produce

(a) OF_2 and O_3 (b) F_2O_2 and NaF
(c) HF and O_2 (d) OF_2 and NaF

13. Fluorine reacts with aqueous $KClO_3$ to produce
(a) $KClO_4$ (b) $KClO_2$
(c) KCl (d) KClO

14. In which of the following reactions is Cl_2 (gas) produced?
(a) $NaCl + K_2Cr_2O_7 + H_2SO_4 \text{ (conc.)} \longrightarrow$
(b) $KCl + Br_2 \longrightarrow$
(c) $Ca(OCl)Cl + H_2O \longrightarrow$
(d) $NaOCl + NH_3 \longrightarrow$

15. $NaHSO_4$ reacts with F_2 to produce mainly
(a) $Na_2S_2O_8$ (b) $Na_2S_2O_5$
(c) $Na_2S_2O_7$ (d) $Na_2S_2O_3$

16. Cl_2 reacts with dilute NaOH and concentrated NaOH to respectively produce
(a) NaClO and $NaClO_2$ (b) $NaClO_3$ and NaClO
(c) NaClO and $NaClO_3$ (d) NaCl and $NaClO_4$

17. Chlorine can be manufactured by the oxidation in air of HCl in the presence of a $CuCl_2$ catalyst at 450°C. The process is known as the
(a) Deacon process (b) Nelson process
(c) Chloride process (d) Solvay process

18. Chlorine acts as an oxidizing agent when it reacts with
(a) O_3 (b) $Fe_2(SO_4)_3$
(c) $FeSO_4$ (d) $KMnO_4$

19. Which of the following will act as the strongest acid?
(a) $Cr(OH)_2$ (b) $ClO_3(OH)$
(c) $PO(OH)_3$ (d) $SO(OH)_2$

20. The standard reduction potentials of the halogens are in the order
(a) $F_2 > Cl_2 > I_2 > Br_2$ (b) $Cl_2 > F_2 > I_2 > Br_2$
(c) $I_2 > Br_2 > Cl_2 > F_2$ (d) $F_2 > Cl_2 > Br_2 > I_2$

21. Which of the following has the highest molar enthalpy of vapourization?
(a) HCl (b) HF (c) HI (d) HBr

22. The electrolysis of brine produces
(a) only Cl_2 (b) NaOH and $NaClO_3$
(c) Cl_2 and NaOH (d) NaCl and NaClO

23. Which of the following reactions does not produce bromine?

(a) $NaBr + MnO_2 + H_2SO_4 \longrightarrow$

(b) $NaBrO_3 + NaBr + H_2SO_4 \longrightarrow$

(c) $MgBr_2 + Cl_2 \longrightarrow$

(d) $NaBr + I_2 \longrightarrow$

24. Bromine reacts with hot and concentrated Na_2CO_3 to produce

(a) $NaBr + NaBrO + CO_2$ (b) $NaBr + NaBrO_4 + CO_2$

(c) $NaBr + NaBrO_3 + CO_2$ (d) $NaBrO + NaBrO_3 + CO_2$

25. Which of the following reactions does not liberate iodine?

(a) $KI + MnO_2 + H_2SO_4 \longrightarrow$

(b) $NaIO_3 + NaHSO_3 \longrightarrow$

(c) $CuSO_4 + KI \longrightarrow$

(d) $NaIO_3 + NaHSO_4 + Cl_2$

26. When solid NaCl and solid $K_2Cr_2O_7$ are heated with concentrated H_2SO_4, a compound is produced in which the oxidation number of $Cr = +6$. The compound is

(a) $Cr_2(SO_4)_3$ (b) CrO_2Cl_2

(c) K_2CrO_4 (d) $KCrO_3Cl$

27. Which of the following halogens is extracted from sea-weeds?

(a) F_2 (b) Cl_2

(c) Br_2 (d) I_2

28. Which of the following compounds is the strongest fluoride-ion acceptor?

(a) SbF_5 (b) AlF_3 (c) IF_7 (d) CaF_2

29. The acid strengths of HF, HCl, HBr and HI increase in the order

(a) $HCl < HBr < HI < HF$ (b) $HBr < HCl < HI < HF$

(c) $HF < HCl < HBr < HI$ (d) $HF < HBr < HCl < HI$

30. The bleaching action of chlorine occurs in the presence of

(a) moisture (b) sunlight

(c) pure oxygen (d) pure sulphur dioxide

31. Which of the following gases shows bleaching action due to reduction?

(a) H_2O_2 (b) H_2S

(c) SO_2 (d) NH_3

32. The boiling points of HF, HCl, HBr and HI follow the order

(a) HF > HCl > HBr > HI (b) HF > HI > HBr > HCl

(c) HI > HBr > HCl > HF (d) HCl > HF > HBr > HI

33. In which of the following reactions is bromine liberated?

(a) $KBr(aq) + I_2 \xrightarrow{\Delta}$ (b) $HI(aq) + KBr(aq) \xrightarrow{\Delta}$

(c) $KBr(aq) + F_2 \xrightarrow{\Delta}$ (d) $KBr(aq) + SO_2 \xrightarrow{\Delta}$

34. Which of the following hydrogen halides has high dielectric constant and low viscosity?

(a) HCl (b) HBr (c) HI (d) HF

35. In which of the following reactions is HF liberated?

(a) $KHF_2 \xrightarrow{\Delta}$ (b) $F_2 + KCl \xrightarrow{\Delta}$

(c) $PH_4F \xrightarrow{\Delta}$ (b) $F_2 + NaOH \longrightarrow$

36. Among the following, which acts as the strongest acid in reactions where HNO_3 behaves like a base?

(a) HI (b) H_3PO_3

(c) HF (d) HIO_4

37. By which of the following reactions is HF prepared industrially?

(a) $CaF_2 + H_2SO_4 \xrightarrow{\Delta}$

(b) $Na_3AlF_6 + Al_2O_3 + H_2SO_4 \xrightarrow{\Delta}$

(c) $F_2 + HNO_3 \xrightarrow{\Delta}$

(d) All of these

38. Hydrofluoric acid cannot be stored in glass vessels because it reacts with glass to form

(a) Na_2SiO_3 and F_2 (b) Na_2SiF_6

(c) SiF_2 (d) $Na_4[SiF_6]$

39. Which of the following reactions does not produce HBr?

(a) $KBr + H_3PO_3 \xrightarrow{\Delta}$

(b) $P(red) + Br_2 + H_2 \xrightarrow{\Delta}$

(c) $NaBr + H_2SO_4(conc.) \xrightarrow{\Delta}$

(d) $Br_2 + NaOH \xrightarrow{\Delta}$

40. The boiling point of HF is unexpectedly higher than those of HCl, HBr and HI because of

(a) the greater polarity of the H—F bond

(b) the intermolecular hydrogen bond formed between H and F

(c) the intramolecular hydrogen bond formed between H and F as a result of the HF molecule becoming highly associated

(d) all of these

41. The bond dissociation energy of HF is approximately twice that of

(a) HCl (b) HBr

(c) F_2 (d) HI

42. Arrange CCl_4, $AlCl_3$, PCl_5 and $SiCl_4$ according to ease of hydrolysis.

(a) $CCl_4 < SiCl_4 < PCl_5 < AlCl_3$

(b) $AlCl_3 < CCl_4 < PCl_5 < SiCl_4$

(c) $CCl_4 < AlCl_3 < PCl_5 < SiCl_4$

(d) $CCl_4 < AlCl_3 < SiCl_4 < PCl_5$

43. Arrange HF, HCl, HBr and HI in decreasing order of bond dissociation energy.

(a) HF > HCl > HBr > HI (b) HI > HBr > HCl > HF

(c) HI > HF > HCl > HBr (d) HBr > HCl > HF > HI

44. The increasing order of the dipole moments of halogen acids is

(a) HI < HBr < HCl < HF (b) HF < HCl < HBr < HI

(c) HBr < HI < HCl < HF (d) HCl < HF < HBr < HI

45. The ionic character of the metal-halogen bond (M—X) in metal halides decreases in the order

(a) M—Br > M—Cl > M—F > M—I

(b) M—I > M—Br > M—Cl > M—F

(c) M—Cl > M—Br > M—I > M—F

(d) M—F > M—Cl > M—Br > M—I

46. Which of the following is arranged in order of increasing ionic character?

(a) $PbCl_2 < SnCl_4 < KCl < MgCl_2$ (b) $SnCl_4 < PbCl_2 < KCl < MgCl_2$

(c) $SnCl_4 < PbCl_2 < MgCl_2 < KCl$ (d) $PbCl_2 < SnCl_4 < MgCl_2 < KCl$

47. Which of the following shows the arrangement of halide ions in increasing order of reducing property?

(a) $Cl^- < F^- < I^- < Br^-$ (b) $F^- < Cl^- < Br^- < I^-$

(c) $Br^- < I^- < F^- < Cl^-$ (d) $I^- < Br^- < Cl^- < F^-$

48. The correct order of arrangement of the acids ClOH (I), BrOH (II) and IOH (III) in order of decreasing acid strength is

(a) I > III > II (b) II > III > I

(c) I > II > III (d) III > II > I

49. Nessler's reagent is used to detect NH_3. This reagent is prepared by mixing

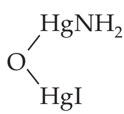
(a) KI (excess) + $HgCl_2$ + KOH

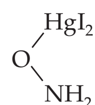
(b) KCl + HgI_2 + KOH

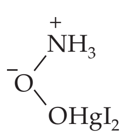
(c) KI (excess) + $HgCl_2$ + $\overset{+}{N}H_4\overset{-}{O}H$

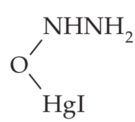
(d) KI (excess) + Hg_2Cl_2 + I_2 solution

50. Ammonia reacts with Nessler's reagent to give a brown precipitate known as iodide of Millon's base. This base is believed to have the structure

(a) 

(b) 

(c) 

(d) 

51. Which of the following statements is correct?

(a) The length of the O—O bond in O_2F_2 is greater than that in H_2O_2.

(b) The length of the O—O bond in O_2F_2 is less than that in H_2O_2.

(c) O_2F_2 does not contain the peroxide bond —O—O— .

(d) The O—O bond distance is the same in H_2O_2 and O_2F_2.

52. Cl_2O (gas) dissolves in a KOH solution to produce

(a) Cl_2O_7 (b) KCl

(c) KClO (d) $KClO_3$

53. Which of the following molecules has the highest bond angle and is V-shaped?

(a) OF_2 (b) Cl_2O

(c) H_2S (d) Br_2O

54. The structure of OF_2 is

(a) tetrahedral with each of two positions occupied by a lone pair of electrons

(b) tetrahedral with one position occupied by a lone pair of electrons

(c) square planar with two positions each occupied by a lone pair of electrons

(d) a pentagonal bipyramid with three positions occupied by a lone pair of electrons each

55. ClO_2 reacts with NaOH to give a mixture of

(a) $NaClO_2$ and $NaClO_4$ (b) $NaClO_2$ and $NaClO_3$

(c) NaClO and $NaClO_2$ (d) $NaClO_3$ and $NaClO_4$

56. ClO_2 reacts with O_3 to give

(a) Cl_2O_4 (b) Cl_2O

(c) Cl_2O_6 (d) ClO_4

57. Among the following oxoacids of chlorine, acidity increases in the order

(a) $HClO < HClO_2 < HClO_3 < HClO_4$

(b) $HClO_4 < HClO_3 < HClO_2 < HClO$

(c) $HClO_2 < HClO_4 < HClO_3 < HClO$

(d) $HClO_3 < HClO < HClO_4 < HClO_2$

58. Among the following conjugate bases of oxoacids of chlorine, which arrangement shows the correct order of increasing hydration energy and basic character?

(a) $ClO^- < ClO_2^- < ClO_3^- < ClO_4^-$

(b) $ClO_4^- < ClO_3^- < ClO_2^- < ClO^-$

(c) $ClO_3^- < ClO_4^- < ClO_2^- < ClO^-$

(d) $ClO_4^- < ClO_3^- < ClO^- < ClO_2^-$

59. The hybridization state of the iodine atom in ICl_2^- is

(a) d^2sp^3 (b) dsp^2 (c) sp^2 (d) sp^3d

60. Which of the following statements is correct regarding the ClO_3 and Cl_2O_6 molecules?

(a) They are paramagnetic and diamagnetic respectively.

(b) They are diamagnetic and paramagnetic respectively.

(c) Both are diamagnetic.

(d) Both are paramagnetic.

61. The structure of Cl_2O_7 is

(a) tetrahedral (b) square pyramidal

(c) pentagonal bipyramidal (d) trigonal bipyramidal

62. Which of the following is not the salt of periodate?

(a) KIO_4
(b) $Na_4I_2O_9$
(c) $Pb_4(IO_5)_2$
(d) Ag_5IO_6

63. The hybridization states of the chlorine atom in the ions ClO_4^-, ClO_3^- and ClO_2^- are respectively

(a) sp^3, dsp^2 and sp^2
(b) dsp^2, sp^3 and sp^2
(c) sp^3 in all the species
(d) sp^3, sp^2 and sp

64. Which of the following is not paramagnetic?

(a) NO_2
(b) O_2^-
(c) ClO_2
(d) Cl_2O_7

65. Which of the following interhalogens does not exist?

(a) BrF_5
(b) IF
(c) IF_7
(d) BrF_3

66. Which of the following is not linear?

(a) $IBrF^-$
(b) ICl_2^-
(c) I_3^+
(d) I_3^-

67. Under anhydrous conditions CCl_4 reacts with HF to produce

(a) CF_4
(b) $CHCl_3$
(c) CH_2Cl_2
(d) CCl_2F_2

68. In spite of being an odd-electron molecule, ClO_2 does not dimerize because

(a) the odd electron is delocalized
(b) the odd electron is localized in the chlorine atom
(c) the two Cl—O bonds do not have the same length
(d) of pπ-pπ bonding in the chlorine atom

69. Which of the following statements is correct?

(a) I_2O_4 exists as $IO^+ \cdot IO_3^-$.
(b) I_4O_9 exists as $I^{3+} \cdot (IO_3^-)_3$.
(c) On decomposition, I_4O_9 gives I_2O_5.
(d) All of these

70. In the absence of a catalyst, $KClO_3$ undergoes a disproportionation reaction to form

(a) $KClO_4$ and $KClO_3$
(b) KCl and O_2
(C) $KClO_4$ and KCl
(d) $KClO_4$ and Cl_2

71. When an aqueous solution of sodium fluoride is electrolysed the gas liberated at the anode is

(a) H_2 (b) O_2

(c) F_2O (d) O_2 and F_2

72. The shape of H_5IO_6 is

(a) irregular tetrahedral (b) square pyramidal

(c) pentagonal bipyramidal (d) octahedral

73. The common form of periodic acid is $HIO_4 \cdot 2H_2O$ or H_5IO_6. This is called

(a) metaperiodic acid (b) dimesoperiodic acid

(c) mesoperiodic acid (d) paraperiodic acid

74. On strong heating, the acid H_5IO_6 gives

(a) I_2O_4 (b) I_2O_5

(c) I_2O_7 (d) HIO_4

75. Which of the following statements is correct for the $CsBr_3$ molecule?

(a) It contains Cs^{3+} and Br^- ions.

(b) It is a complex compound.

(c) It contains Cs^+ and Br_3^- ions.

(d) It contains Cs^+, Br_2 and Br^- ions in its crystal lattice.

76. Certain ions, with properties similar to halide ions, have two or more atoms of which at least one is nitrogen. Such ions are called

(a) interhalogen compounds (b) nitriles

(c) pseudonitriles (d) pseudohalides

77. The hybridization states of the central atoms of the ions I_3^-, ICl^- and ICl_4^- are respectively

(a) sp^2, dsp^2, pd^3 (b) sp^3d, sp^3d and sp^3d^2

(c) sp^3d, sp^3d, dsp^2 (d) sp, sp, dsp^2

78. The hybridization state of the central atom of BrF_5 and the shape of the molecule are respectively

(a) sp^3d, T-shaped (b) sp^3d^2, octahedral

(c) sp^3d^2, square pyramidal (d) sp^3d^3, trigonal bipyramidal

79. The hybridization state of the central atom of IF_7 and the shape of the molecule are respectively

(a) sp^3d^3, pentagonal bipyramidal

(b) sp^3d^3, square antiprismic

(c) sp^3d^2, octahedral

(d) sp^3d^3, square based pyramidal

80. Which of the following is a pseudohalide ion?

(a) N_3^- (b) ONC^-

(c) SCN^- (d) All of these

81. Which of the following is not a pseudohalide ion?

(a) $SeCN^-$ (b) $TeCN^-$

(c) SCN^- (d) $S_4N_4^{2-}$

82. Which of the following compounds is not an "interpseudohalogen"?

(a) Cl_2N_3 (b) BrCN (c) ClCN (d) ICN

83. Which of the following are not pseudohalogens?

(a) Cyanogens (b) Thiocyanogens

(c) Azidocyanogens (d) Azidocarbon disulphides

84. Which of the following is the most electronegative?

(a) N_3^- (b) Br^-

(c) I^- (d) NCS^-

85. Which of the following is arranged in decreasing order of pseudohalogen character?

(a) $(SeCN)_2 > (CN)_2 > (SCN)_2$ (b) $(SCN)_2 > (CN)_2 > (SeCN)_2$

(c) $(CN)_2 > (SeCN)_2 > (SCN)_2$ (d) $(SeCN)_2 > (SCN)_2 > (CN)_2$

• Type 2 •

Choose the correct options. More than one option is correct.

86. Which of the following will displace the halogen from the solution of the halide?

(a) Br_2 added to an NaCl solution

(b) Cl_2 added to a KBr solution

(c) Cl_2 added to an NaF solution

(d) Br_2 added to a KI solution

87. Chlorine is produced by the

(a) electrolysis of an aqueous solution of NaCl

(b) action of concentrated HCl on MnO_2

(c) action of concentrated H_2SO_4 on NaCl in the presence of MnO_2

(d) evaporation of sea water

88. Which of the following exist?

(a) ICl_3 (b) FCl_3

(c) IF_7 (d) BrF_3

89. Chlorine behaves as an oxidizing agent upon reaction with

(a) $Fe_2(SO_4)_3$ (b) O_3

(c) $Na_2S_2O_3$ (d) $NaNO_2$

90. Which of the following compounds react with fluorine?

(a) NaCl (b) KF

(c) B_2O_3 (d) Al_2O_3

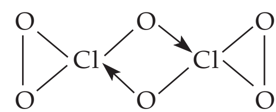
91. Which of the following are used in the preparation of Nessler's reagent?

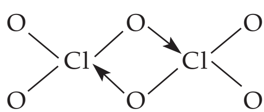
(a) Hg_2Cl_2 (b) KI

(c) $HgCl_2$ (d) NaOH

92. By which of the following structures may Cl_2O_6 be represented?

(a) $ClO_2^+ ClO_4^-$

(b) 

(c) 

(d) $ClO_3^- ClO_3^+$

93. By which of the following reactions is $HClO_4$ prepared?

(a) $HClO_3 \xrightarrow{\Delta}$ (b) $KClO_4 + HCl \xrightarrow{\Delta}$

(c) $NH_4Cl + KClO_3 \xrightarrow{\Delta}$ (d) $POCl_3 + HNO_3 \xrightarrow{\Delta}$

94. Which of the following molecules are angular?

(a) F_2O_2 (b) Cl_2O

(c) KI_3 (d) ClO_2

95. Which of the following are V-shaped?

(a) ClF_2^+ (b) BrF_2^+

(c) ICl_2^+ (d) Cl_2F^+

96. Which of the following halides form infinite chains?

(a) BeF_2 (b) $BeCl_2$

(c) $AlCl_3$ (d) I_2Cl_6

97. Which of the following halides hydrolyses easily?

(a) BCl_3 (b) $SiCl_4$

(c) PCl_3 (d) PCl_5

98. Which of the following halides are stable to hydrolysis?

(a) NH_4Cl (b) CCl_4

(c) SF_6 (d) $SnCl_4$

99. Which of the following are bent?

(a) F_3^- (b) Br_2^+ (c) I_3^- (d) I_3^+

100. Which of the following molecules undergoes disproportionation under suitable conditions?

(a) $HClO_2$ (b) $HClO_4$ (c) NaCl (d) NaOCl

Answers

1. c	**2.** a	**3.** d	**4.** b	**5.** c
6. a	**7.** c	**8.** d	**9.** b	**10.** c
11. d	**12.** d	**13.** a	**14.** c	**15.** a
16. c	**17.** a	**18.** c	**19.** b	**20.** d
21. b	**22.** c	**23.** d	**24.** c	**25.** d
26. b	**27.** d	**28.** a	**29.** c	**30.** a
31. c	**32.** b	**33.** c	**34.** d	**35.** a
36. c	**37.** a	**38.** b	**39.** c	**40.** b
41. d	**42.** d	**43.** a	**44.** a	**45.** d
46. c	**47.** b	**48.** c	**49.** a	**50.** a
51. b	**52.** c	**53.** d	**54.** a	**55.** b
56. c	**57.** a	**58.** b	**59.** d	**60.** c
61. a	**62.** c	**63.** c	**64.** d	**65.** b
66. c	**67.** d	**68.** a	**69.** d	**70.** c
71. b	**72.** d	**73.** d	**74.** b	**75.** c
76. d	**77.** b	**78.** c	**79.** a	**80.** d
81. d	**82.** a	**83.** c	**84.** a	**85.** b
86. b, d	**87.** a, b, c	**88.** a, c, d	**89.** c, d	**90.** a, b, c, d
91. b, c, d	**92.** a, c	**93.** a, b	**94.** b, d	**95.** a, b, c, d
96. a, b	**97.** a, b, c, d	**98.** b, c	**99.** b, d	**100.** a, d

Hints to More Difficult Problems

1. They are of similar size.

4. The low dissociation energy of F_2 arises from the repulsion between the unpaired electrons in the two atoms. Because of the large size of I_2, the degree of dissociation is low.

5. The oxidation number of Cl in ClO^- is +1, +5 in ClO_3^- and –1 in Cl^-.

26. This is the basis of the chromyl chloride test.

29. Size and bond length increase in this order, and pK_a decreases. Therefore, acid strength increases.

32. The boiling point of HF is highest due to hydrogen bonding, i.e., HF is the associated molecule $(HF)_n$. In the rest of the halides, boiling point increases with molar mass—they do not undergo hydrogen bonding because of their large size and low electronegativity.

34. HF is a liquid. See the answer to Q. 32.

39. (a) $NaBr + H_2SO_4 \longrightarrow NaHSO_4 + HBr$

(b) $2H\overset{-1}{Br} + H_2\overset{+6}{S}O_4 \longrightarrow 2H_2O + \overset{0}{Br_2} + \overset{+4}{S}O_2$

Here HBr is produced in reaction (a), and is a reducing agent. HBr reduces H_2SO_4 to SO_2 and is itself oxidized to Br_2 so instead of getting HBr we get a mixture of Br_2 and SO_2.

42. PCl_5 readily undergoes coordination number expansion to a maximum covalence of six.

45. Apply Fajans' rules.

47. Use the values of the respective standard reduction potentials.

49. Nessler's reagent is a mixture of $K_2[HgI_4]$ and KOH. It is prepared by the following sequence of reactions.

$$2KI + HgCl_2 \longrightarrow 2KCl + HgI_2$$

$$HgI_2 + 2KI \longrightarrow K_2[HgI_4] \xrightarrow{+KOH} \text{Nessler's reagent}$$

57. The oxidation number of Cl in $HClO_4$ is +7 (maximum), the ClO_4^- ion is the largest in size and the pK_a value of $HClO_4$ is the least, meaning that it has the greatest K_a (dissociation constant). This accounts for the maximum acid strength of $HClO_4$.

58. Use the Brönsted-Lowry concept.

70. $4K\overset{+5}{Cl}O_3 \longrightarrow 3K\overset{+7}{Cl}O_4 + K\overset{-1}{Cl}$

This is a disproportionation reaction.

74. $$\underset{\text{paraperiodic acid}}{2H_5IO_6} \xrightarrow[-4H_2O]{100°C} \underset{\text{periodic acid}}{2HIO_4} \xrightarrow{200°C} \underset{\text{iodine pentoxide}}{I_2O_5} + O_2 + H_2O$$

86. Order of electronegative effect of halogens

89. $4Cl_2 + S_2O_3^{2-} + 5H_2O \longrightarrow 8Cl^- + 2SO_4^{2-} + 10H^+$

$Cl_2 + NO_2^- + H_2O \longrightarrow 2Cl^- + NO_3^- + 2H^+$

The oxidation number of Cl_2 changes from 0 to –1. Hence, Cl_2 behaves as an oxidizing agent.

100. $\overset{+3}{ClO_2^-} \longrightarrow \overset{+4}{ClO_2} + \overset{-1}{Cl^-}$ oxidation number

$\overset{+1}{OCl^-} \longrightarrow \overset{-1}{Cl} + \overset{+5}{ClO_3^-}$ oxidation number

❑

10

The Noble Gases

Choose the correct option. Only one option is correct.

1. Which of the following is a superfluid?
(a) Krypton I (b) Argon II
(c) Helium II (d) Helium I

2. Helium II is the most extraordinary liquid with
(a) zero viscosity and very high heat conductivity
(b) zero viscosity and low heat conductivity
(c) very high viscosity and zero heat conductivity
(d) very high viscosity and very high heat conductivity

3. Compounds formed when noble gases get trapped in the cavities of the crystal lattices of certain organic and inorganic compounds are known as
(a) polyhydrates (b) supercooled solids
(c) stoichiometric compounds (d) clathrates

4. XeF_4 reacts violently with water to give
(a) $Xe + O_2$ (b) $XeO_3 + O_2 + HF$
(c) $Xe + O_2 + HF + XeO_3$ (d) $XeOF_3$

5. In clathrate atoms or molecules the bond formed is
(a) metallic (b) covalent
(c) ionic (d) They do not form bonds.

6. Solid XeF_6 exists as
(a) XeF_4^+ and F_2^- (b) XeF_5^+ and F^-
(c) XeF_7^- and F^+ (d) Xe^{4+} and F^{4-}

7. The fluoride of xenon with zero dipole moment is
(a) XeF_6 (b) XeO_3 (c) XeF_4 (d) XeF_2

8. Noble gases are difficult to liquefy because their
(a) dispersion forces are large
(b) dispersion forces are small
(c) ionization energies are low
(d) affinity energies are high

9. The element which has the highest first ionization energy is
(a) hydrogen (b) xenon
(c) fluorine (d) helium

10. Which of the following statements is incorrect for helium?
(a) It has a positive Joule–Thomson coefficient above 40 K.
(b) Its spontaneous expansion causes it to warm up.
(c) It has to be compressed before it can liquefy.
(d) It has a negative Joule-Thomson coefficient above 40 K.

11. Xenon trioxide (XeO_3) has a
(a) T-shaped structure
(b) square-pyramidal structure
(c) trigonal pyramidal structure
(d) irregular tetrahedral structure

12. Which of the following noble gases is the most polarized?
(a) Radon (b) Krypton
(c) Xenon (d) Helium

13. Which of the following noble gases is the least polarized?
(a) Radon (b) Krypton
(c) Xenon (d) Helium

14. Which of the following mixtures of noble gases are used to produce laser beams?
(a) He and Kr (b) Ar and Rn
(c) Kr and Ar (d) He and Ne

15. XeO_4 contains
(a) four π-bonds, and the remaining four electron pairs form a tetrahedron
(b) three π-bonds, and the remaining five electron pairs form a trigonal bipyramid
(c) three π-bonds, and the remaining four electron pairs form a square-planar structure
(d) four π-bonds, and the remaining three electron pairs form a pyramid

16. The structure of XeO_3F_2 is

(a) square pyramidal
(b) pentagonal bipyramidal
(c) trigonal bipyramidal
(d) octahedral

17. The structure of XeO_4 is

(a) pyramidal
(b) square planar
(c) tetrahedral
(d) that of an irregular tetrahedron

18. XeO_3F_2 contains

(a) three π-bonds, and the remaining five electron pairs form a trigonal bipyramid
(b) two π-bonds, and the remaining six electron pairs form an octahedron
(c) four π-bonds, and the remaining four electron pairs form a tetrahedron
(d) five electron pairs and three lone pairs

19. The structure of XeF_6 is

(a) square pyramidal
(b) that of a distorted octahedron
(c) pyramidal
(d) trigonal bipyramidal

20. XeF_6 has

(a) a tetrahedral structure with one lone pair
(b) a trigonal bipyramidal structure with two lone pairs
(c) a capped octahedral structure with one lone pair
(d) a capped octahedral structure with two lone pairs

21. The structure of XeO_2F_2 is

(a) square pyramidal
(b) trigonal bipyramidal
(c) octahedral
(d) tetrahedral

22. XeO_3 contains

(a) four π-bonds, and the remaining four electron pairs form a tetrahedron with one corner occupied by a lone pair
(b) six electron pairs and two lone pairs
(c) two π-bonds, and two corners of a tetrahedron occupied by a lone pair
(d) three π-bonds and the remaining four electron pairs form a tetrahedron with one corner occupied by a lone pair

23. XeO_2F_2 contains

(a) four π-bonds and two σ-bonds
(b) two π-bonds, and the remaining five electron pairs form a trigonal bipyramid with one equatorial position occupied by a lone pair

(c) one π-bond, and the remaining six electron pairs form an octahedron with one position occupied by a lone pair

(d) three π-bonds, and the remaining four electron pairs form a trigonal bipyramid with two equatorial positions occupied by a lone pair

24. $XeOF_4$ contains

(a) six electron pairs forming an octahedron with two positions occupied by lone pairs

(b) two π-bonds and the remaining six electron pairs, forming an octahedron

(c) three π-bonds, and the remaining four electron pairs forming tetrahedron

(d) one π-bond, and the remaining six electron pairs forming an octahedron with one position occupied by a lone pair

25. XeF_4 contains

(a) four electron pairs and four lone pairs

(b) six electron pairs and two lone pairs

(c) three electron pairs and three lone pairs

(d) two electron pairs and six lone pairs

26. Helium is suitable for low-temperature gas thermometry because of its

(a) high transition temperature

(b) real behaviour

(c) low boiling point and near-ideal behaviour

(d) high boiling point and high polarizability

27. XeO_6^{4-} contains

(a) eight electron pairs and no lone pairs

(b) three electron pairs and three lone pairs

(c) two electron pairs and six lone pairs

(d) four electron pairs and four lone pairs

28. The structure of XeF_2 is

(a) planar triangular (b) linear

(c) square planar (d) pyramidal

29. In which of the following pairs of noble gases is there a large difference in van der Waals radii?

(a) Kr and Xe (b) He and Ne

(c) Ne and Ar (d) Ar and Kr

30. The reaction of Xe with an excess of F_2 at high pressure and 25°C yields

(a) XeF_2 (b) XeF_4 (c) XeF_6 (d) XeF_3

31. The slow hydrolysis of XeF_6 gives

(a) XeO_2F_2 (b) XeO_3 (c) $XeOF_4$ (d) $[XeO_6]^{4-}$

32. Which of the following statements is correct?

(a) Helium-5 and helium-6 are radioactive nuclides with shorthalf-lives.

(b) ${}^4_2He$ is obtained from the decay of ${}^3_1H$.

(c) Helium is the most abundant noble gas in the atmosphere.

(d) Helium-4 has a low molecular viscosity and a large mean free path.

33. XeF_4 reacts with NO_2 to produce

(a) $NO_2F + Xe$ (b) $N_2 + Xe$

(c) $N_2O + XeO_3$ (d) $NO_2F_2 + XeO_3$

34. XeF_4 reacts with BCl_3 to produce

(a) BF_3 and $XeCl_4$ (b) BF_3, Cl_2 and Xe

(c) BF_3 only (d) Cl_2 only

35. Which of the following statements is correct?

(a) Noble gases have very high ionization energy.

(b) Noble gases have positive electron affinity.

(c) Fluorides and oxides of xenon are relatively stable.

(d) Noble gases can be liquefied above their critical temperatures and below their inversion temperatures at 1 atmosphere.

36. The first noble-gas compound, prepared by Bartlett and Lohman, was

(a) $O_2^+[Pt\,F_6]^-$ (b) XeF_6 (c) $Xe^+[Pt\,F_6]^-$ (d) XeF_2

37. Which of the following statements is incorrect?

(a) XeF_2 is a powerful reducing agent.

(b) XeF_2 is obtained by the direct reaction between F_2 and Xe at high pressure.

(c) XeF_2 undergoes alkaline hydrolysis to give O_2 and Xe.

(d) XeF_2 contains four electron pairs and four lone pairs.

38. The slow hydrolysis of XeF_4 produces

(a) XeO_2F_2 (b) XeO_3

(c) $XeOF_4$ (d) $[XeO_6]^{4-}$

39. Deep-sea divers breathe using a mixture of

(a) O_2 and H_2 (b) O_2 and Kr

(c) O_2 and He (d) O_2 and Ar

40. Which of the following statements is correct for helium?

(a) Among the noble gases, it has the maximum enthalpy of vapourization.

(b) Its van der Waals constants (*a* and *b* values) are large due to strong intermolecular attraction.

(c) Liquid helium can be produced above critical temperature and below inversion temperature.

(d) The inversion temperature (T_i) of helium is negative at 0°C as well as 100°C at 1 atm.

41. XeF_2 contains

(a) three electron pairs from a trigonal bipyramid, and three lone pairs in the equatorial position

(b) four electron pairs from a trigonal bipyramid, and three lone pairs in the equatorial position.

(c) five electron pairs from a trigonal bipyramid, and three lone pairs in the equatorial position

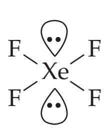
(d) three electron pairs from a pentagonal bipyramid, and five lone pairs from a trigonal bipyramid

Answers

1. c	**2.** a	**3.** d	**4.** c	**5.** d
6. b	**7.** c	**8.** b	**9.** d	**10.** a
11. c	**12.** c	**13.** d	**14.** d	**15.** a
16. c	**17.** c	**18.** a	**19.** b	**20.** c
21. b	**22.** d	**23.** b	**24.** d	**25.** b
26. c	**27.** a	**28.** b	**29.** b	**30.** c
31. b	**32.** a	**33.** a	**34.** b	**35.** c
36. c	**37.** a	**38.** b	**39.** c	**40.** d
41. c				

Hints to More Difficult Problems

7.



The molecule is symmetrical and so the vector sum of the individual dipole moments is zero.

9. Small size and filled shell ($1s^2$)

10. $\mu_{JT} = -\left(\frac{\partial T}{\partial p}\right)_H$

12. The van der Waals radius is the greatest and the van der Waals interaction between the atoms maximum for Xe.

13. The van der Waals radius is the smallest and the van der Waals interaction between the atoms minimum for He.

❑

11

Aluminium

• Type 1 •

Choose the correct option. Only one option is correct.

1. Aluminium and gallium have nearly the same covalent radius because of the
- (a) greater shielding effect of the s electrons of gallium atoms
- (b) poor shielding effect of the s electrons of gallium atoms
- (c) poor shielding effect of the d electrons of gallium atoms
- (d) greater shielding effect of the d electrons of gallium atoms

2. The electrolytic reduction of alumina to aluminium by the Hall-Heroult process is carrried out in the presence of
- (a) NaCl
- (b) fluorite
- (c) cryolite which induces the mixture to melt at a temperature lower than the melting point of alumina
- (d) cryolite which raises the melting point of alumina

3. Aluminium is obtained by the
- (a) reduction of alumina with coke
- (b) electrolysis of alumina dissolved in molten cryolite
- (c) reduction of alumina with chromium
- (d) heating cryolite and alumina

4. Bauxite is purified by
- (a) Hall's process
- (b) Baeyer's process
- (c) Serpeck's process
- (d) all of these

5. Anhydrous aluminium chloride is prepared by heating aluminium
- (a) with concentrated HCl
- (b) with dry chlorine gas

(c) with a dilute HCl solution (d) carbide with dry HCl gas

6. Aluminium burns in dinitrogen at high temperature to produce
(a) aluminium nitride (b) aluminium azide
(c) aluminium nitrate (d) alumina

7. Aluminium dissolves in aqueous sodium hydroxide to produce
(a) Na_3AlO_6 (b) $NaAl(OH)_4$
(c) $NaAl_2O_4$ (d) all of these

8. Thermite is a mixture of iron oxide and
(a) zinc powder (b) sodium metal
(c) coke (d) aluminium powder

9. In the aluminothermite process, aluminium acts as
(a) a reducing agent (b) an oxidizing agent
(c) a common solder (d) a flux

10. The reducing powers of Al, Ga In and Tl are in the order
(a) In > Ga > Al > Tl (b) Al > Tl < In > Ga
(c) Tl > In > Ga > Al (d) Al > Ga > In > Tl

11. Which of the following forms only covalent compounds?
(a) Thallium (b) Aluminium
(c) Boron (d) Gallium

12. Aluminium chloride ionizes in an aqueous solution because
(a) its dissociation constant is low
(b) it forms a dimer in an aqueous solution
(c) it is a Lewis acid
(d) its total hydration energy exceeds the ionization energy of the system

13. Which of the following metals does not show an inert-pair effect?
(a) Indium (b) Aluminium (c) Gallium (d) Thallium

14. Duralumin is an alloy of Al with
(a) Mn and Mg (b) Mg and Ni
(c) Mg, Mn and Cu (d) Mg, Cr and Mn

15. Which of the following statements is correct?
(a) The hydroxides of boron and aluminium are amphoteric.
(b) The hydroxide of boron is basic while that of aluminium is amphoteric.
(c) The hydroxide of aluminium is more acidic than that of boron.
(d) The hydroxide of boron is acidic while that of aluminium is amphoteric.

16. The salts of aluminium and zinc can be distinguished from each other by
(a) the flame test
(b) the borax bead test
(c) the cobalt nitrate test
(d) treatment with an excess of an NaOH solution

17. Which of the following reactions is not a part of the Goldschmidt aluminothermic process?
(a) $Fe_2O_3 + 2Al \longrightarrow Al_2O_3 + 2Fe$
(b) $Cr_2O_3 + 2Al \longrightarrow Al_2O_3 + 2Cr$
(c) $3Mn_3O_4 + 8Al \longrightarrow 4Al_2O_3 + 9Mn$
(d) $3ZnO + 2Al \longrightarrow Al_2O_3 + 3Zn$

18. In the Al_2Cl_6 dimer,
(a) all the Al—Cl bonds are equivalent
(b) three Al—Cl bonds are equivalent and three are not
(c) two Al—Cl bonds are equivalent and four are not
(d) two Al—Cl bonds are not equivalent and four are equivalent

19. Which of the following gases is evolved when aluminium is boiled in a concentrated alkali solution?
(a) Only O_2
(b) A mixture of O_2 and H_2
(c) Only H_2
(d) All of these.

20. Aluminium is thermodynamically stable because
(a) a thin layer of aluminium oxide is formed on its surface, protecting it from further attack
(b) it has a low hydration power
(c) its ionization energy is greater than that of copper
(d) it has a low standard reduction potential

21. During the extraction of aluminium,
(a) a graphite-lined steel tank serves as an anode and a graphite rod as a cathode
(b) a graphite-lined steel tank acts as a cathode and a graphite rod as an anode
(c) cryolite acts as an anode as well as a cathode
(d) a graphite rod acts as an anode and molten aluminium as a cathode

22. At low temperatures,
(a) $AlCl_3$ exists as a close-packed lattice of Cl^- and Al^{3+}, occupying tetrahedral holes

(b) $AlCl_3$ exists as a close-packed lattice of Cl^- and Al^{3+}, occupying trigonal holes

(c) $AlCl_3$ exists as a close-packed lattice of Cl^- and Al^{3+}, occupying octahedral holes

(d) $AlCl_3$ reacts with Al to produce AlCl

23. Aluminium hydride is best made by the reaction between

(a) $Li[AlH_4]$ and $AlCl_3$
(b) Li and CaH_2
(c) LiCl and $Li[AlH_4]$
(d) $Li[AlH_4]$ and Cl_2

24. In the structure of α-$AlCl_3$, each Al participates in

(a) four bridges
(b) six bridges
(c) three bridges
(d) twelve bridges

25. Which of the following statements is incorrect?

(a) Cryolite is added to alumina to lower the fusion temperature and make the melt a good conductor.

(b) Aluminium forms an $[AlF_6]^{3-}$ ion.

(c) Anhydrous aluminium chloride cannot be prepared by heating hydrated aluminium chloride ($AlCl_3 \cdot 6H_2O$) because of the hydrolysis of $AlCl_3$.

(d) $AlCl_3$ is a high-melting solid while AlF_3 is a low-melting volatile solid.

• *Type 2* •

Choose the correct options. More than one option is correct.

26. Which of the following alloys contain aluminium?

(a) Devarda's alloy
(b) Invar
(c) Rolled gold
(d) Type metal

27. Which of the following double salts form acidic solutions when dissolved in water?

(a) Fusion mixture
(b) Alum
(c) Mohr's salt
(d) Carnallite

28. Potash alum is used as a

(a) disinfectantant
(b) water softener
(c) mordant in the textile industry
(d) fibre in the polymer industry

29. Which of the following minerals contain aluminium?

(a) Fluorspar (b) Feldspar
(c) Mica (d) Carborundum

30. Aluminium is not purified by

(a) Baeyer's process (b) Ostwald's process
(c) Hoope's process (d) Serpeck's process

31. The general formula of alums is $X^{I}Y^{III}(SO_4)_3 \cdot 12H_2O$. Which of the following combinations are alums?

(a) K^{I} and Al^{III} (b) K^{I} and Cr^{III}
(c) NH_4^+ and Al^{III} (d) Na^+ and Tl^{III}

32. Which of the following statements are correct?

(a) All alums crystallize in the octahedral form and produce isomorphous series of double salts.
(b) All alums are double salts and have large values of water of crystallization.
(c) Aluminium sulphate is useful as a mordant in dying and printing.
(d) Alums are used in coagulation, the purification of water, and the tanning of leather.

33. Aluminium reacts with hot concentrated NaOH solution to produce

(a) $NaAlO_2 + H_2$ (b) $Na_3AlO_2 + H_2$
(c) $Na_3AlO_3 + H_2$ (d) $Na_2AlO_4 + H_2$

34. Two different forms of alumina are known. These are

(a) α-Al_2O_3 (b) γ-Al_2O_3
(c) β-Al_2O_3 (d) δ-Al_2O_3

35. Which of the following trivalent cations can form alums?

(a) Mn^{3+} (b) Co^{3+}
(c) Fe^{3+} (d) Cr^{3+}

36. Which of the following statements are correct?

(a) $AlCl_3$ reacts with Grignard's reagent to form trialkyl aluminium.
(b) Triethyl aluminium is used to prepare the Ziegler–Natta catalyst.
(c) Aluminium trimethyl forms dimers and has three-centre bonds involving sp^3-hybrid orbitals on Al and C in the Al—C—Al bridge.
(d) AlCl is covalent and very stable.

Answers

1. c	**2.** c	**3.** b	**4.** d	**5.** b
6. a	**7.** b	**8.** d	**9.** a	**10.** d
11. c	**12.** d	**13.** b	**14.** c	**15.** d
16. c	**17.** d	**18.** d	**19.** c	**20.** a
21. b	**22.** c	**23.** a	**24.** b	**25.** d
26. a, c	**27.** b, c	**28.** a, b	**29.** b, c	**30.** a, b, d
31. a, b, c	**32.** a, b	**33.** a, c	**34.** a, b	**35.** a, b, c, d
36. a, b, c				

Hints to More Difficult Problems

10. Consider the standard electrode potentials.

11. Being a nonmetal, boron forms covalent compounds.

13. The $3s^2$ electron is not inert in Al, in contrast to the other metals in its series.

15. $B(OH)_3 + 2H_2O \rightleftharpoons H_3O^+ + [B(OH)_4]^-$
$Al(OH)_3$ does not undergo an acidic reaction in water.

16. Upon conducting the charcoal-block oxidizing-flame test using $Co(NO_3)_2$, we get coloured beads. Al gives blue $Al_2O_3 \cdot CoO$ and Zn gives green $ZnO \cdot CoO$. This is how salts of Al and Zn can be distinguished.

❑

12

Tin and Lead

• Type 1 •

Choose the correct option. Only one option is correct.

1. Tin is extracted from its ore, cassiterite, by
(a) electrolytic reduction (b) carbon-monoxide reduction
(c) carbon reduction (d) the aluminothermic process

2. Tin is not refined by
(a) liquation (b) zone refining
(c) poling (d) any of these

3. Moderately concentrated nitric acid reacts with tin to produce metastannic acid, which is represented by
(a) $H_2Sn_5O_{11}$ (b) $H_2Sn_5O_2$
(c) $H_2Sn_4O_{10}$ (d) $H_2Sn_4O_6$

4. Tin (II) oxide is not prepared by
(a) boiling a stannous chloride solution with Na_2CO_3
(b) heating tin oxalate (SnC_2O_4) in the absence of air
(c) heating tin hydroxide in air
(d) heating tin (IV) oxide in air

5. The geometry of $SnCl_2$ is
(a) linear (b) pyramidal
(c) V-shaped (d) plane triangular

6. Which of the following crystals is formed when $SnCl_2 \cdot 2H_2O$ is treated with concentrated HCl?
(a) $SnCl_4 \cdot 5H_2O$ (b) $HSnCl_3 \cdot 2H_2O$
(c) $H_2SnCl_6 \cdot 8H_2O$ (d) $H_2SnCl_4 \cdot 4H_2O$

7. Tin (II) sulphide dissolves in yellow ammonium sulphide to give

(a) thiostannate $[(NH_4)_2SnS_3)]$ (b) thiostannite $[(NH_4)_2SnS_4)]$
(c) tin (IV) sulphide (d) a mixture of SnS_2 and H_2SnS_6

8. The shape of $SnCl_4$ is

(a) square planar (b) irregular tetrahedral
(c) square pyramidal (d) tetrahedral

9. Which of the following is correct?

(a) $SnS_2 + Na_2S \longrightarrow Na_2SnS_3$
(b) $SnS_2 + (NH_4)_2S \longrightarrow (NH_4)_2SnS_3$
(c) $SnS_2 + NaOH \longrightarrow Na_2SnO_3 + Na_2SnS_3 + H_2O$
(d) $SnS_2 + HNO_3 \longrightarrow Sn(NO_3)_2 + H_2SO_4 + SO_2 + H_2O$

10. Which of the following statements is incorrect?

(a) An acidified solution of tin (II) chloride becomes cloudy on dilution with water.
(b) Hydrogen sulphide reacts with an acidified solution of tin (II) chloride to produce a white precipitate.
(c) Tin (IV) sulphide dissolves in yellow ammonium sulphide to produce a clear solution, which on acidification gives a yellow precipitate and hydrogen sulphide.
(d) The type of allotropy in which two allotropes are equally stable at the transition temperature is called enantiotropy.

11. Which of the following compounds is a solid?

(a) SnI_4 (b) CCl_4
(d) $SiBr_4$ (d) None of these

12. Among the following, the most stable dihalide is

(a) CX_2 (b) SiX_2
(c) GeX_2 (d) SnX_2

13. Which of the following statements is incorrect?

(a) Anhydrous stannous chloride is prepared by heating hydrated stannous chloride crystals in a stream of hydrogen chloride.
(b) Due to hydrolysis by water, stannous chloride forms a white precipitate of basic stannous chloride $[Sn(OH)Cl \cdot H_2O]$.
(c) The hydrolysed product of stannous chloride does not go into solution in the presence of HCl.
(d) The hydrolysed product of stannous chloride goes into the solution in the presence of dilute HCl.

14. Which of the following statements is incorrect for tin (IV) chloride?

(a) It is obtained by passing hydrogen chloride over heated tin

(b) It is a colourless liquid which fumes in moist air owing to hydrolysis.

(c) It is not completely hydrolysed by water unless the solution is dilute, and in the presence of a little water it is possible to obtain solid $SnCl_4 \cdot 5H_2O$.

(d) It is ionic, and presumably contains $[Sn(H_2O)_4]^{4+}$ ions.

15. Tin produces a low crackling sound on bending. This is known as tin

(a) poison (b) cry

(c) plague (d) sound

16. Which of the following is correct for the tin that exhibits enantiotropy among its three allotropic forms?

(a) Grey tin (α) $\xrightleftharpoons{500\text{ K}}$ brittle tin $\xrightleftharpoons{434\text{ K}}$ white tin (β)

(b) Brittle tin $\xrightleftharpoons{286.5\text{ K}}$ white tin (β) $\xrightleftharpoons{200\text{ K}}$ grey tin (α)

(c) Grey tin (α) $\xrightleftharpoons{286.5\text{ K}}$ white tin (β) $\xrightleftharpoons{434\text{ K}}$ brittle tin

(d) White tin (β) $\xrightleftharpoons{400\text{ K}}$ grey tin $\xrightleftharpoons{286.5\text{ K}}$ brittle tin

17. Which of the following halides is the least stable?

(a) PbI_4 (b) PbI_2 (c) $SnBr_4$ (d) $SnCl_4$

18. Massicot is prepared by heating

(a) tin in the presence of CO_2 (b) cerussite

(c) minium (d) litharge

19. In which of the following acids is lead easily soluble?

(a) Sulphuric acid (b) Nitric acid

(c) Hydrochloric acid (d) Acetic acid

20. Common solder is an alloy of

(a) Sn and Sb (b) Sn and Pb

(c) Sn and Cu (d) Sn and Zn

21. Type metal is an alloy of

(a) Zn, Sb and Pb (b) Cu, Sn and Pb

(c) Sb, Sn and Pb (d) Fe, Sn and Pb

22. The lead chamber process is used for the manufacture of

(a) sulphuric acid (b) basic lead carbonate

(c) red lead (d) lead sulphate

23. Which of the following compounds is known as chrome red, in which the oxidation number of Cr = +6?

(a) $PbCrO_3 \cdot Pb(OH)_2$ (b) $PbCrO_4 \cdot CrO_3$
(c) $PbCrO_4 \cdot Pb_3O_4$ (d) $PbCrO_4 \cdot PbO$

24. Which of the following compounds is known as chrome yellow in which the configuration of chromium is $[Ar]3d^0 4s^0$?

(a) $PbCrO_4$ (b) $PbCr_2O_7$
(c) $PbCrO_4 \cdot Cr_2O_3$ (d) Pb_2CrO_4

25. Lead sulphate is soluble in a solution of concentrated

(a) sulphuric acid (b) hydrochloric acid
(c) ammonium acetate (d) lead nitrate

26. In lead storage batteries, we use

(a) Pb as the cathode and PbO_2 as the anode
(b) PbO_2 as the cathode and Pb as the anode
(c) a lead plate as the cathode and SnO_2 as the anode
(d) one lead dioxide plate as the cathode and another as the anode

27. The lead accumulator cell is a secondary cell and is rechargable. The acid solution used in this cell comprises

(a) H_2SO_4 and $CH_3CO_2NH_4$ (b) H_2SO_4
(c) H_2SO_4 and $PbSO_4$ (d) H_2SO_4 and CH_3CO_2H

28. The least melting metal among the following is

(a) tin (b) carbon (c) germanium (d) lead

29. The red and yellow forms of lead (II) oxide are known respectively as

(a) litharge and galene (b) litharge and massicot
(c) massicot and vermilion (d) red lead and heavy spar

30. Which of the following compounds disproportionates easily?

(a) $PbCrO_4$ (b) Pb_3O_4 (c) $PbCl_2$ (d) PbI_4

31. On descending the group of which lead is a member, the

(a) stability of the +4 oxidation state of lead decreases
(b) stability of the +2 oxidation state of lead increases
(c) tendency of the inert-pair effect decreases
(d) tendency of the inert-pair effect increases up to Ge and then decreases

32. Which of the following is known as mosaic gold?

(a) As_2O_3 (b) PbS
(c) SnS_2 (d) PbI_2

33. Which of the following is known as white lead?

(a) $Pb(OH)_2 \cdot 2PbCO_3$
(b) $2Pb(OH)_2 \cdot Pb(CH_3COO)_2 \cdot PbS$
(c) $PbCO_3 \cdot PbSO_4$
(d) $PbO \cdot 2PbCO_3$

34. Lead is extracted from its ore by the

(a) lead chamber process
(b) Pattinson process
(c) self-reduction process
(d) self-oxidation process

35. "Softening of lead" means the

(a) conversion of PbS into Pb
(b) removal of tin from common solder
(c) removal of impurities from Pb
(d) addition of tin to lead

36. A white solid insoluble in cold water but dissolved in hot water responds positively to the golden spangles test. The white solid is

(a) $PbCrO_4$
(b) PbI_2
(c) $PbCO_3$
(d) $PbCl_2$

37. What is used as an antiknocking agent in petrol?

(a) Lead tetraacetate
(b) Tetraethyl lead
(c) Lead carbonate
(d) Diethyl lead

38. White lead (basic lead acetate) is prepared by the reaction between

(a) lead acetate and Na_2CO_3 solution
(b) lead carbonate and CO_2
(c) lead acetate and CO_2
(d) lead acetate and NaOH solution

39. The only stable lead (IV) oxosalt is lead (IV)

(a) acetate, $Pb(CH_3COO)_2$
(b) acetate, $Pb(CH_3COO)_4$
(c) perchlorate, $Pb(ClO_4)_4$
(d) periodate, $Pb(IO_4)_4$

40. The expansion of the octet for Sn and Pb explains the formation of

(a) $PbCl_6^{2-}$
(b) $Pb(OH)_6^{2-}$
(c) $Sn(OH)_6^{2-}$
(d) all of these

• *Type 2* •

Choose the correct options. More than one option is correct.

41. In which of the following reactions can $SnCl_2/Sn^{2+}$ act as a reducing agent?

(a) $SnCl_2 + I_2 \longrightarrow SnCl_4 + SnI_4$
(b) $SnCl_2 + HgCl_2 \longrightarrow SnCl_4 + Hg_2Cl_2$

(c) $MnO_4^- + H^+ + Sn^{2+} \longrightarrow Mn^{2+} + Sn^{4+} + H_2O$

(d) $Sn^{2+} + Au^{3+} \longrightarrow Sn^{4+} + Au$

42. Which of the following statements are correct?

(a) $SnCl_4$ reacts with concentrated HCl to produce H_2SnCl_6.

(b) $SnCl_4$ reacts with concentrated NH_4Cl to produce $(NH_4)_2SnCl_6$ which is known as "pink salt".

(c) $SnCl_2$ is more covalent than $SnCl_4$.

(d) On strong heating, tin oxalate produces tin (II) oxide.

43. Which of the following minerals contain tin?

(a) Pyrolusite (b) Tinstone

(c) Cerussite (d) Cassiterite

44. In its compounds, tin exhibits the oxidation numbers

(a) +2 (b) +4 (c) +6 (d) +1

45. The shape of $SnCl_2$ is similar to that of

(a) H_2O (b) NO_2^+ (c) O_3 (d) NH_2^-

46. By which of the following reactions is tetraethyl lead (TEL) prepared?

(a) $C_2H_5I + NaPb \longrightarrow$

(b) $C_2H_5I + NaCl + Pb(C_2H_5)_4 \longrightarrow$

(c) $PbCl_2 + C_2H_5MgI \longrightarrow$

(d) $C_2H_6 + Cl_2 + Pb \longrightarrow$

47. Which of the following minerals contain lead?

(a) Anglesite (b) Cerussite

(c) Heavy spar (d) Galena

48. Basic lead carbonate is prepared by the

(a) Dutch process (b) German process

(c) electrolytic process (d) Raschig process

49. Which of the following show the right products?

(a) $Pb_3O_4 + HNO_3 \longrightarrow Pb(NO_3)_2 + PbO_2 + H_2O$

(b) $PbO_2 + NaOH \longrightarrow Na_2PbO_4 + H_2O$

(c) $PbS + H_2O_2 \longrightarrow PbSO_4 + H_2O$

(d) $PbS + O_3 \longrightarrow PbSO_4 + O_2$

50. Which of the following show the right products?

(a) $MnSO_4 + PbO_2 + HNO_3 \longrightarrow HMnO_4 + PbSO_4 + Pb(NO_3)_2 + H_2O$

(b) $Cr(OH)_3 + KOH + PbO_2 \longrightarrow K_2CrO_4 + K_2PbO_2 + H_2O$

(c) $Pb_3O_4 + HCl \longrightarrow PbCl_2 + Cl_2 + H_2O$

(d) $Pb + H_2O + O_2 \longrightarrow Pb(OH)_4$

Answers

1. c	**2.** b	**3.** a	**4.** d	**5.** c
6. b	**7.** a	**8.** d	**9.** b	**10.** b
11. a	**12.** d	**13.** c	**14.** a	**15.** b
16. c	**17.** a	**18.** b	**19.** d	**20.** b
21. c	**22.** a	**23.** d	**24.** a	**25.** c
26. a	**27.** b	**28.** a	**29.** b	**30.** d
31. a	**32.** c	**33.** a	**34.** c	**35.** c
36. d	**37.** b	**38.** a	**39.** b	**40.** d
41. a, b, c, d	**42.** a, b, d	**43.** b, c, d	**44.** a, b	**45.** a, c, d
46. a, c	**47.** a, b, d	**48.** a, b, c	**49.** a, c, d	**50.** a, b, c

Hints to More Difficult Problems

7. $SnS + (NH_4)_2S_2 \longrightarrow (NH_4)_2SnS_3$

12. Due to the inert-pair effect.

17. Pb^{4+} oxidizes I^- to I_2.

$PbI_4 \longrightarrow PbI_2 + I_2$

25. $\underset{\text{insoluble}}{PbSO_4(s)} + 2CH_3COONH_4 \longrightarrow \underset{\text{soluble}}{Pb(CH_3COO)_2} + (NH_4)_2SO_4$

28. Tin does not have a packed structure.

30. See the hint to Q. 17.

31. Due to the strong inert-pair effect in lead

34. (a) $2PbS + 3O_2 \longrightarrow 2PbO + 2SO_2$

(b) $PbS + 2O_2 \longrightarrow PbSO_4$

(c) $PbS + 2PbO \longrightarrow 3Pb + SO_2$

(d) $PbS + 2PbSO_4 \longrightarrow Pb + 2PbO + 3SO_2$

Reactions (b) and (d) play a minor role.

44. The oxidation number of Sn is +2 in $SnCl_2$ and +4 in $SnCl_4$.

45. Like $SnCl_2$, all are V-shaped.

❑

13

Copper, Silver and Gold

• *Type 1* •

Choose the correct option. Only one option is correct.

1. The second and third ionization energies of copper are much lower than those of alkali metals. This accounts for the

(a) existence of colourless diamagnetic ions and complexes in the I oxidation state

(b) existence of coloured paramagnetic ions and complexes in the II and III oxidation states

(c) linear geometry of CuO

(d) formation of various alloys

2. Matte contains

(a) Cu_2S, FeS and silica (b) Cu_2S, FeO and silica

(c) Cu_2S, CuO and silica (d) Cu_2S, Cu_2O and silica

3. By which of the following reactions is blister copper obtained?

(a) $Cu_2S + FeO \longrightarrow 2Cu + FeO$

(b) $Cu_2S + FeS \longrightarrow 2Cu + FeS_2$

(c) $Cu_2S + 2Cu_2O \longrightarrow 6Cu + SO_2$

(d) $Cu^{2+} + Fe \longrightarrow Fe^{2+} + Cu$

4. The most stable oxidation states of Group 11 metals in their compounds are

(a) Cu(+2), Ag(+1) and Au(+3)

(b) Cu(+2), Ag(+1) and Au(+1)

(c) Cu(+1), Ag(+2) and Au(+3)

(d) Cu(+2), Ag(+2) and Au(+2)

5. Which of the following compounds is known as bornite or peacock's ore?
(a) $CuAl_6(PO_4)_4(OH)_8 \cdot 4H_2O$ (b) $CuFeS_2$
(c) Cu_5FeS_4 (d) $YBa_2Cu_3O_7$

6. Copper is extracted from its sulphide ore by
(a) the carbon reduction process
(b) a displacement reaction
(c) electrolytic reduction
(d) self-reduction of the oxide and sulphide of copper

7. In an aqueous solution, Cu(+1) salts are unstable because
(a) Cu(+1) has a $3d^{10}$ configuration
(b) the change in free energy of the overall reaction is zero
(c) they disproportionate easily to the Cu and Cu(+2) states
(d) they disproportionate easily to the Cu(+2) and Cu(+3) states

8. The crystal structure of copper is a
(a) simple cubic lattice (b) bcc lattice
(c) ccp lattice (d) hcp lattice

9. A few Cu(I) salts are coloured. The colour arises from
(a) d–d transition
(b) charge-transfer spectra
(c) the large wavelengths of the rays absorbed by the solutions
(d) none of these

10. Which of the following reactions is used to estimate copper gravimetrically?
(a) $Cu^{2+} + 4NH_3 \longrightarrow [Cu(NH_3)_4]^{2+}$
(b) $2Cu^{2+} + 4I^- \longrightarrow 2CuI + I_2$
(c) $2Cu^{2+} + 4CN^- \longrightarrow CuCN + (CN)_2$
(d) $2Cu^{2+} + SO_3^{2-} + 2SCN^- + H_2O \longrightarrow 2CuSCN + H_2SO_4$

11. When a $CuSO_4$ solution is treated with $K_4[Fe(CN)_6]$, a brown precipitate of
(a) $Cu_2[Fe(CN)_6]_2$ (b) $Cu[Fe(CN)_6]$
(c) $Cu_2[Fe(CN)_6]$ (d) $Cu_2[Cu(CN)_6]$
is obtained.

12. When a $CuSO_4$ solution is treated with an excess of KCN, a colourless complex salt in which copper has a d^{10} configuration is obtained. The salt is
(a) $K_2[Cu_2(CN)_4]$ (b) $K_2[Cu(CN)_6]$
(c) $K_3[Cu(CN)_4]$ (d) $K_4[Cu(CN)_5]$

13. $CuSO_4$ reacts with an excess of hypo solution to produce a Cu^{I} complex of

(a) $Cu_2S_2O_3$ (b) $Na_3[Cu(S_2O_3)_2]$
(c) $Na_4[Cu_6(S_2O_3)_5]$ (d) $Cu_4[Na_6(S_2O_3)_5]$

14. During the extraction of copper from chalcopyrites, iron is removed as

(a) $Fe_3(PO_4)_2$ (b) Fe_2O_3 (c) $Fe_2(SiO_3)_3$ (d) $FeSiO_3$

15. Blister copper is

(a) electrolytically refined copper
(b) a mixture of impure copper and silver
(c) copper containing 2% impurity
(d) present in the anode mud in an electrolytic process

16. A $CuSO_4$ solution reacts with an Na_2CO_3 solution to produce

(a) $CuCO_3$ (b) $CuCO_3 \cdot Cu(HCO_3)_2$
(c) $CuCO_3 \cdot Cu(OH)_2$ (d) Cu_2O

17. Which of the following statements is correct? Cu (II) acetate is

(a) paramagnetic, dimeric and hydrated
(b) paramagnetic, monomeric and hydrated
(c) diamagnetic, dimeric and not hydrated
(d) paramagnetic, tetrameric and hydrated

18. Which of the following is polymeric in the vapour state?

(a) $Cu(CH_3COO)_2$ (b) CuF_2
(c) $CuCl$ (d) $CuSO_4$

19. The reactivity of copper is low because of its

(a) high enthalpy of sublimation and low ionization energy
(b) high enthalpy of sublimation and high ionization energy
(c) low enthalpy of sublimation and high ionization energy
(d) low enthalpy of sublimation and low ionization energy

20. The melting point of copper is higher than that of zinc because

(a) copper has a bcc structure
(b) the atomic volume of copper is higher
(c) the d electrons of copper are involved in metallic bonding
(d) the s as well as d electrons of copper are involved in metallic bonding

21. Which of the following compounds is a superconductor?

(a) $CaTiO_3$ (b) $Cu_3(AsO_3)_2 \cdot Cu(CH_3COO)_2$
(c) $YBa_2Cu_8O_{7-x}$ (d) $YBa_2Cu_3O_{7-x}$

22. The ionization energy of copper is higher than that of potassium though both have a 4s configuration because the d electrons in copper

(a) form a poor shield, making copper smaller

(b) form a poor shield, making copper bigger

(c) are strongly shielded, making copper smaller

(d) are strongly shielded, making copper bigger

23. When a solution of KI is added to a sample of Cu^{2+} ions

(a) I^- oxidizes Cu^{2+} to CuI, and is reduced to I_2

(b) I^- reduces Cu^{2+} to CuI, and is oxidized to I_2

(c) I^- oxidizes Cu^{2+} to Cu, and is reduced to I_2

(d) I^- reduces Cu^{2+} to Cu, and is oxidized to I_2

24. The melting points of Cu, Ag and Au follow the order

(a) Cu > Ag > Au (b) Cu > Au > Ag

(c) Au > Ag > Cu (d) Ag > Au > Cu

25. Which of the following statements is correct?

(a) The tetrahedral $[CuCl_4]^{2-}$ ion is green.

(b) The tetrahedral $[CuCl_4]^{2-}$ ion is blue, and the square-planar $[CuCl_4]^{2}$ ion is red.

(c) The tetrahedral $[CuCl_4]^{2-}$ ion is orange, and the square-planar $[CuCl_4]^{2-}$ ion is yellow.

(d) The tetrahedral as well as square-planar $[CuCl_4]^{2-}$ ions are bright yellow.

26. When heated to above 800°C, $Cu(NO_3)_2$ yields

(a) $N_2 + CuO$ (b) $Cu_2O + CuO + N_2O$

(c) $Cu + N_2$ (d) Cu_2O

27. The blue colour of a cupric salt solution in water is due to the formation of a hydrated cupric ion. The hydrated ion is

(a) octahedral with two long bonds trans to each other and four short bonds trans to each other

(b) tetrahedral with two long bonds trans to each other and two short bonds cis to each other

(c) octahedral with two long bonds cis to each other and four short bonds trans to each other

(d) octahedral with two short bonds cis to each other and four long bonds trans to each other

28. Silver bromide dissolves in a hypo solution to produce

(a) $Ag_2S_2O_3$ (b) $[Ag(S_2O_3)_2]^-$

(c) $[Ag(S_2O_3)_2]^{3-}$ (d) $[Ag_6(S_2O_3)_5]^{4+}$

29. AgCl is insoluble in water but readily soluble in a dilute ammonia solution because

(a) NH_3 is a better solvent than water

(b) NH_3 is a stronger base than water

(c) Ag^+ forms a complex with NH_3 to produce $[Ag(NH_3)_2]^+$

(d) the dipole moment of water is higher than that of NH_3

30. The extraction of silver from its ore involving KCN, air and an active metal is known as

(a) Pattinson's process

(b) the amalgamation process

(c) the McArthur–Forrest process

(d) Parke's process

31. Which of the following ions disproportionates in water?

(a) Au^{3+} (b) $[Au(CN)_4]^-$

(c) $[AuCl_4]^-$ (d) Au^+

32. Gold and platinum dissolve in aqua regia to produce respectively

(a) $H[AuCl_4]$ and $H[PtCl_3]$ (b) $H[AuCl_4]$ and $H_2[PtCl_6]$

(c) $H_2[AuCl_6]$ and $H[PtCl_4]$ (d) $H_2[AuCl_6]$ and $[PtCl_6]$

33. Chloroauric acid reacts with sodium hydroxide to produce

(a) $Au(OH)_3$ (b) $[Au(OH)_4]^{2-}$

(c) Au_2O_3 (d) $K[AuCl_4]$

34. The metallic radius of gold is almost identical with that of silver because of

(a) transition metal contraction

(b) the same crystal structure of silver and gold

(c) the high electropositive character of gold in comparison to silver

(d) the effect of lanthanide contraction in gold

35. Silver chloride fuses with sodium carbonate to produce

(a) Ag_2CO_3 (b) Ag_2O

(c) AgOH (d) Ag

36. Silver is extracted from Ag_2S by

(a) fusing it with KCl, and electrolysing the melt

(b) reducing it with zinc

(c) treating it with sodium cyanide followed by zinc

(d) roasting it and reducing the resultant product by smelting

37. Silver is refined by

(a) cupellation
(b) poling
(c) the van Arkel method
(d) liquation

38. The ores of Ag and Au are concentrated using their solubility in

(a) HCl
(b) HNO_3
(c) H_2SO_4
(d) KCN

39. Zinc is used to extract silver

(a) by solvent extraction from molten lead in Parke's process
(b) by solvent extraction from molten gold in the cyanide process
(c) by carbon monoxide reduction in Mond's process
(d) by solvent extraction from molten iron in the LD process

40. In the electrolytic refining of silver, the anode mud obtained contains

(a) Zn, Ag and Au
(b) Zn, Cu, Ag and Au
(c) Au
(d) Cu, Ag and Au

41. Which of the following silver salts is insoluble in water?

(a) $AgClO_4$
(b) Ag_2SO_4
(c) AgF
(d) $AgNO_3$

42. During the extraction of Ag and Au using an excess of KCN, soluble complexes are formed. These complexes, which have 10 d electrons in Ag and Au, are

(a) $K_2[Ag(CN)_4]$ and $K_3[Ag(CN)_4]$
(b) $K[Ag(CN)_2]$ and $K[Au(CN)_2]$
(c) $K_2[Ag(CN)_3]$ and $K_2[Au(CN)_3]$
(d) $K_4[Ag_6(CN)_{10}]$ and $K_4[Au_6(CN)_{16}]$

43. Which of the following reactions will occur on heating $AgNO_3$ to above its melting point?

(a) $2AgNO_3 \longrightarrow 2Ag + 2NO_2 + O_2$
(b) $2AgNO_3 \longrightarrow 2Ag + N_2 + 3O_2$
(c) $2AgNO_3 \longrightarrow 2AgNO_2 + O_2$
(d) $2AgNO_3 \longrightarrow Ag + NO + O_2$

44. When $AgNO_3$ is strongly heated, the gases evolved are

(a) N_2O and N_2
(b) N_2O_5 and O_2
(c) N_2O_3 and O_2
(d) NO_2 and O_2

45. In photography AgBr is mainly used as

(a) a fixer
(b) an emulsion
(c) a light-sensitive material
(d) a developer

46. AgCl dissolved in an excess of solutions of NH_3, KCN and $Na_2S_2O_3$ produces complex ions. They are, respectively,

(a) $[Ag(NH_3)_2]^+$, $[Ag(CN)_2]^-$ and $[Ag(S_2O_3)_2]^{3-}$

(b) $[Ag(NH_3)_2]^{2+}$, $[Ag(CN)_2]^{3-}$ and $Ag_4(S_2O_3)_5]^{2-}$

(c) $[Ag(NH_3)_2]^{2+}$, $[Ag(CN)_2]^+$ and $[Ag_2(S_2O_3)_2]^{2-}$

(d) $[Ag(NH_3)_4]^+$, $[Ag(CN)_4]^{3-}$ and $[Ag_2(S_2O_3)_2]^{2-}$

47. Gold (III) chloride exists as a planar Au_2Cl_6 molecule in

(a) only the solid state
(b) only the vapour state
(c) only the liquid state
(d) the solid as well the vapour state

• *Type 2* •

Choose the correct options. More than one option is correct.

48. Which of the following are correctly matched?

(a) Turquoise $\longrightarrow$ $(CuAl_6PO_4)_4(OH)_8 \cdot 4H_2O$

(b) Peacock ore $\longrightarrow$ Cu_4FeS_2

(c) Malachite $\longrightarrow$ $CuCO_3 \cdot Cu(OH)_2$

(d) Chalcopyrites $\longrightarrow$ $CuFeS_2$

49. Which of the following are correctly matched?

(a) Brass $\longrightarrow$ Cu, Sn
(b) Nickel silver $\longrightarrow$ Cu, Ni, Zn
(c) Phosphor bronze $\longrightarrow$ Cu, Sn, P
(d) Fool's gold $\longrightarrow$ CuS_2

50. Which of the following statements are correct in connection with the extraction of silver?

(a) Silver is obtained as a by-product in the extraction of copper, lead and zinc.

(b) Silver is obtained from the anode slime formed in the electrolytic refining of copper and zinc.

(c) Zinc is used to extract silver by solvent extraction from molten lead in Parke's process.

(d) None of these

51. Which of the following does not disproportionate?

(a) Cu^+ (b) Au^{3+} (c) Cu^{2+} (d) Au^+

52. In which of the following complexes do copper ions show an oxidation state of +1?

(a) $[Cu(CN)_4]^{3-}$ (b) $[CuCl_2]^-$ (c) $[CuCl_3]^{2-}$ (d) $[CuCl_4]^{3-}$

53. Which of the following are correctly matched?

(a) Schweitzer's reagent $\longrightarrow$ An ammoniacal solution of cupric hydroxide

(b) Bordeaux mixture $\longrightarrow$ $CuSO_4$ and $Ca(OH)_2$

(c) Semiconductor $\longrightarrow$ $YBa_2Cu_3O_7$

(d) Horn silver $\longrightarrow$ $AgNO_3$

54. During the extraction of Ag and Au using a KCN solution, cyanide ions react with metal ions as

(a) a reducing agent (b) a complexing agent

(c) an oxidizing agent (d) a Lewis acid

Answers

1. b	**2.** a	**3.** c	**4.** a	**5.** c
6. d	**7.** c	**8.** c	**9.** b	**10.** d
11. c	**12.** c	**13.** c	**14.** d	**15.** c
16. c	**17.** a	**18.** c	**19.** b	**20.** c
21. d	**22.** a	**23.** b	**24.** b	**25.** c
26. d	**27.** a	**28.** c	**29.** c	**30.** c
31. d	**32.** b	**33.** a	**34.** d	**35.** d
36. c	**37.** a	**38.** d	**39.** a	**40.** c
41. b	**42.** b	**43.** c	**44.** d	**45.** c
46. a	**47.** d	**48.** a, c, d	**49.** b, c	**50.** a, b, c
51. b, c	**52.** a, b, c, d	**53.** a, b	**54.** a, b	

Hints to More Difficult Questions

4. Value of effective nuclear charge.

6. $Cu_2S + 2Cu_2O \longrightarrow 6Cu + SO_2$

$2Cu^+ \rightleftharpoons Cu^{2+} + Cu$

$$K_{eq} = \frac{[Cu^{2+}]}{[Cu^+]} = 1.6 \times 10^6$$

The high value of K_{eq} indicates that the reaction will proceed from left to right.

13. $CuSO_4 + Na_2S_2O_3 \longrightarrow Na_2SO_4 + CuS_2O_3$

$6CuS_2O_3 + Na_2S_2O_3 \longrightarrow Na_4[Cu_6(S_2O_3)_5] + Na_2S_4O_6$

28. $AgBr + 2Na_2S_2O_3 \longrightarrow Na_3[Ag(S_2O_3)_2] + NaBr$

29. Small cations may polarize a complex ion so much that the cation and the anion are pulled apart.

$AgCl + 2NH_3 \longrightarrow [Ag(NH_3)_2]^+Cl^-$

31. $3Au^+ \longrightarrow 2Au + Au^{3+} \quad K = 1 \times 10^{10}$

The high value of K indicates that disproportionation occurs.

52. (a) In $Cu(CN)_4^{3-}$, $x - 4 = -3 \Rightarrow x = +1$.

(b) In $CuCl_2^-$, $x - 2 = -1 \Rightarrow x = +1$.

(c) In $CuCl_3^{2-}$, $x - 3 = -2 \Rightarrow x = +1$.

(d) In $CuCl_4^{3-}$, $x - 4 = -3 \Rightarrow x = +1$.

In all these cases, x is the oxidation state of Cu.

❑

14

Zinc and Mercury

• *Type 1* •

Choose the correct option. Only one option is correct.

1. The electronic configurations of Zn and Hg are respectively

(a) $3d^{10}4s^2$ and $4d^{10}5s^2$

(b) $3d^{10}4s^2$ and $4f^{14}\ 4d^{10}5s^2$

(c) $3d^{10}4s^2$ and $4f^{14}5d^{10}6s^2$

(d) $4f^{14}5d^{10}5s^2$ and $4f^{14}5d^{10}7s^2$

2. Which of the following metals shows a well-established oxidation state of +1 in its compounds?

(a) Mg (b) Hg (c) Zn (d) Cd

3. Zinc and mercury are respectively the

(a) last member of the 3d and the first member of the 5d transition series

(b) first member of the 4d and the last member of the 5d transition series

(c) last member of the 3d and the last member of the 5d transition series

(d) last member of the 3d and the last member of the 6d transition series

4. The mercury (I) ion is always

(a) [Hg—Hg] (b) $[Hg—Hg]^{2+}$

(c) $[Hg—Hg]^{4+}$ (d) Hg^{2+}

5. Zinc is extracted from ZnS by the

(a) calcination of ZnS followed by hydrogen reduction at 400°C

(b) calcination of ZnS followed by carbon dioxide reduction

(c) roasting of ZnS followed by aluminium reduction at 1200°C in a muffle furnace

(d) roasting of ZnS followed by carbon monoxide reduction at 1200°C in a smelter

6. The purest zinc is made by

(a) Mond's process (b) zone refining

(c) the van Arkel method (d) poling

7. Which of the following is known as 'philosopher's wool'?

(a) $ZnSO_4 \cdot 7H_2O$ (b) $ZnS + BaSO_4$

(c) ZnO (d) $ZnCO_3$

8. Which of the following structures does ZnO have?

(a) Wurtzite (b) Rutile

(c) Spinel (d) Fluorite

9. Which of the following mixtures is known as Lucas reagent?

(a) Anhydrous $FeSO_4$ and O_3

(b) Anhydrous $MgCl_2$ and $LiAlH_4$

(c) Anhydrous $ZnCl_2$ and concentrated HCl

(d) Anhydrous Na_2SO_4 and concentrated HCl

10. Granulated zinc is made by

(a) displacing Zn from a $ZnSO_4$ solution

(b) zone refining

(c) pouring molten zinc into molten nickel

(d) pouring molten zinc into water

11. Lithopone is a white pigment, and is a mixture of

(a) $BaSO_4$ and $ZnCO_3$ (b) $BaSO_4$ and ZnS

(c) BaS and ZnO (d) $ZnCl_2$ and ZnS

12. A $ZnSO_4$ solution is boiled with an $NaHCO_3$ solution to produce

(a) $Zn(OH)_2$ (b) $ZnCO_3$

(c) $ZnHCO_3 \cdot ZnO$ (d) $ZnCO_3 \cdot Zn(OH)_2$

13. Galvanized iron pipes are made by 'hot dipping'

(a) zinc in molten iron (b) iron in molten nickel

(c) iron in molten zinc (d) iron in molten magnesium

14. $ZnSO_4$ is boiled with Na_2CO_3 to produce

(a) $ZnCO_3 \cdot Zn(OH)_2$ (b) $ZnCO_3$

(c) $ZnCO_3 \cdot ZnSO_4$ (d) $ZnCO_3 \cdot Na_2SO_4$

15. ZnO, a white solid, is a covalent molecule, and adopts a

(a) diamond structure (b) rock-salt structure
(c) bcc structure (d) spinel structure

16. Which of the following pairs are isomorphous?

(a) Blue vitriol and white vitriol
(b) White vitriol and Mohr's salt
(c) Calgon and microcosmic salt
(d) White vitriol and epsom salt

17. Among the following, which is the most thermally stable, and used in the gravimetric determination of zinc?

(a) $ZnCO_3$ (b) $Zn(NO_3)_2$
(c) $Zn_2P_2O_7$ (d) $ZnNH_4PO_4$

18. The formula of basic zinc acetate is

(a) $(CH_3COO)_2Zn \cdot ZnCO_3$ (b) $(CH_3COO)_2Zn \cdot ZnO$
(c) $(CH_3COO)_2Zn \cdot Zn_4O$ (d) $(CH_3COO)_2Zn \cdot Zn(OH)_2$

19. Zinc oxide is normally white but turns yellow on heating and becomes white again on cooling, because of

(a) d–d transition spectra as well as a crystal defect
(b) the two-dimensional network structure of ZnO
(c) its high transition temperature (T_c)
(d) various types of lattice defects because of which the oxygen ion is lost during heating

20. The ionic radii of Group 12 metals Zn, Cd and Hg are smaller than those of Group 2 metals because Zn, Cd and Hg have

(a) 10 d electrons which shield the nuclear charge poorly
(b) 10 d electrons which shield the nuclear charge strongly
(c) 10 d electrons which have a large radius ratio
(d) 10 d electrons which have a large exchange energy

21. The structure of zinc blend is similar to that of diamond,

(a) with half the positions occupied by sulphur and one-fourth by zinc
(b) with half the positions occupied by sulphur and half by zinc
(c) with one-fourth of the positions occupied by sulphur and half by zinc
(d) with one-fourth of the positions occupied by sulphur and one-fourth by zinc

22. Which of the following is covalent?

(a) $ZnCl_2$ (b) $CdCl_2$ (c) $SnCl_2$ (d) $HgCl_2$

23. Which of the following oxides does not sublime on heating?

(a) HgO (b) $HgCl_2$

(c) As_2O_3 (d) NH_4Cl

24. Which of the following is arranged in order of decreasing thermal stability?

(a) $Zn > Hg > Cd$ (b) $Cd > Hg > Zn$

(c) $Zn > Cd > Hg$ (d) $Hg > Cd > Zn$

25. Which of the following oxides can exist in yellow as well as red forms?

(a) ZnO (b) PbO (c) CdO (d) HgO

26. White ZnO on heating loses oxygen and become yellow. The colour is due to defects in the solid structure. Choose the correct option

(a) The number of defects increases with temperature and is zero at transition temperature.

(b) The number of defects increases with temperature and is zero at absolute zero.

(c) The number of defects decreases with temperature and is zero at absolute zero.

(d) The number of defects decreases with temperature and is zero at transition temperature.

27. Which of the following are arranged in the correct order of increasing melting point?

(a) $ZnCl_2 < ZnBr_2 < ZnI_2 < ZnF_2$

(b) $ZnF_2 < ZnI_2 < ZnBr_2 < ZnCl_2$

(c) $ZnF_2 < ZnCl_2 < ZnBr_2 < ZnI_2$

(d) $ZnCl_2 < ZnF_2 < ZnBr_2 < ZnI_2$

28. The salts of which of the following metals are extensively hydrated?

(a) Pb (b) Cd

(c) Hg (d) Zn

29. The ions of metals of Group 12 (Zn, Cd and Hg) have a complete d shell, and so

(a) behave like superconductors

(b) are very high melting solids

(c) do not behave like transition metals

(d) behave like semiconductors

30. Zinc reacts with very dilute nitric acid to produce

(a) $NH_4NO_2 + ZnO_2^{2-}$ (b) $ZnO_2^{2-} + Zn^{2+}$

(c) $N_2O + N_2 + Zn^{2+}$ (d) $NH_4NO_3 + Zn^{2+}$

31. Mercury vapours are

(a) tetratomic (b) hexatomic

(c) monatomic (d) diatomic

32. The metals of Group 12 are softer than other transition metals because

(a) Group 12 metals have a cage-like structure

(b) Group 12 metals have high ionization energies

(c) s as well as d electrons take part in metallic bonding

(d) d electrons do not take part in metallic bonding

33. Group 12 metals are relatively noble because of their

(a) high enthalpy of sublimation, ionization energy and enthalpy of hydration

(b) low enthalpy of sublimation, ionization energy and enthalpy of hydration

(c) high enthalpy of sublimation and ionization energy, and low enthalpy of hydration

(d) high enthalpy of sublimation, low ionization energy and high enthalpy of hydration

34. Which of the following compounds is used as an electrode of the second kind?

(a) $Hg_2(NO_3)_2$ (b) $HgCl_2$

(c) HgS (d) Hg_2Cl_2

35. Which of the following is arranged in order of increasing melting point?

(a) $HgF_2 < HgCl_2 < HgI_2 < HgBr_2$

(b) $HgF_2 < HgCl_2 < HgBr_2 < HgI_2$

(c) $HgI_2 < HgBr_2 < HgCl_2 < HgF_2$

(d) $HgBr_2 < HgI_2 < HgCl_2 < HgF_2$

36. All mercurous compounds are

(a) diamagnetic in the solid state as well as in solution

(b) paramagnetic in the solid state as well as in solution

(c) diamagnetic in the solid state and paramagnetic in solution

(d) paramagnetic in the solid state and diamagnetic in solution

37. Which of the following halides of mercury is the least hydrolysed by water?

(a) HgF_2 (b) $HgCl_2$

(c) $HgBr_2$ (d) HgI_2

38. Hg_2Cl_2 (calomel) and $HgCl_2$ (corrosive sublimate) react separately with liquor ammonia to produce respectively

(a) $Hg(NH_2)Cl + Hg$ and $Hg(NH_2)Cl$

(b) $Hg(NH_2)Cl$ and $Hg(NH_2)Cl + Hg$

(c) $Hg(NH_2)Cl + HgCl_2$ and $Hg(NH_2)Cl + Hg_2Cl_2$

(d) $Hg(NH_2)Cl + Hg$ and $Hg(NH_2)Cl + Hg$

39. Mercury is the only metal which is a liquid at room temperature. This is due to the

(a) high viscosity of mercury

(b) large surface tension of mercury

(c) weak metallic bonding because of its $d^{10}s^2$ configuration, and low van der Waals forces among the mercury molecules

(d) strong metallic bonding due to its $d^{10}s^2$ configuration and strong van der Waals forces among the mercury molecules

40. When an excess of $SnCl_2$ is added to an $HgCl_2$ solution,

(a) Hg_2Cl_2 (b) Hg

(c) Sn (d) $[SnCl_6]^{4-}$

is produced.

41. Corrosive sublimate is made by heating

(a) Hg_2SO_4 and NaCl (b) Hg_2Cl_2 and Hg_2O

(c) $HgSO_4$ and NaCl (d) $HgSO_4$ and HgS

42. Calomel is made by treating

(a) $Hg_2(NO_3)_2$ with HCl

(b) $Hg(NO_3)_2$ with NaCl

(c) $Hg_2(NO_3)_2$ and Hg with aqua regia

(d) $HgSO_4$ with NaCl

43. Nessler's reagent is a mixture of

(a) $HgCl_2$ and KI (excess)

(b) $HgCl_2$, KI (excess) and liquor ammonia

(c) $HgCl_2$, KI (excess) and KOH

(d) $K_2[HgI_4]$ and KI

44. Among the following,

(a) Cd (b) Zn (c) Na (d) Fe

does not form amalgams.

45. Millon's base has

(a) a three-dimensional framework of Hg_2N with OH^- and water molecules occupying spacious cavities and channels

(b) the composition $Hg_2ONH_2 \cdot HI$

(c) a three-dimensional framework of HgN_2 with OH^- and NH_3 molecules occupying spacious cavities and channels

(d) a perovskite structure

46. SO_2 gas is passed through an aqueous suspension of corrosive sublimate ($HgCl_2$), in order to produce

(a) $HgSO_4$ and HCl (b) Hg_2Cl_2

(c) Hg_2SO_4 (d) $HgSO_4$

47. $HgCl_2$ is a solid containing

(a) an angular Cl—Hg—Cl molecule

(b) a linear Cl—Hg—Cl molecule

(c) a T-shaped Cl—Hg—Cl molecule

(d) a pyramidal Cl—Hg—Cl molecule

48. $ZnSO_4$ reacts with the excess of a KCN solution to produce the complex ion

(a) $[Zn(CN)_6]^{4-}$ with an octahedral structure

(b) $[Zn(CN)_4]^{2-}$ with a square-planar structure

(c) $[Zn(CN)_2]^-$ with a linear structure

(d) $[Zn(CN)_4]^{2-}$ with a tetrahedral structure

49. Which of the following statements is correct?

(a) In $[Zn(NCS)_4]^{2+}$, the ligand is bonded through S, but in $[Cd(SCN)_4]^{2+}$ the ligand is bonded through N.

(b) In $[Zn(NCS)_4]^{2+}$, the ligand is bonded through N, but in $[Cd(SCN)_4]^{2+}$ the ligand is bonded through S.

(c) In $[Zn(NCS)_4]^{2+}$ as well as $[Cd(SCN)_4]^{2+}$, the ligands are bonded through S.

(d) In $[Zn(NCS)_4]^{2+}$ as well as $[Cd(SCN)_4]^{2+}$, the ligands are bonded through N.

50. Which of the following has been arranged in order of increasing bond strength?

(a) $Zn_2^{2+} < Hg^{2+} < Cd^{2+}$ (b) $Cd_2^{2+} < Hg_2^{2+} < Zn_2^{2+}$

(c) $Zn_2^{2+} < Cd_2^{2+} < Hg_2^{2+}$ (d) $Hg_2^{2+} << Cd_2^{2+} < Zn_2^{2+}$

• *Type 2* •

Choose the correct options. More than one option is correct.

51. Which of the following statements are correct?

(a) $ZnSO_4$ dissolves in liquor ammonia to form a tetrahedral complex.

(b) Mercurous and cuprous ions are represented respectively as Hg_2^{2+} and Cu_2^{2+}.

(c) ZnS is precipitated from a $ZnSO_4$ solution in an alkaline medium by H_2S.

(d) Granulated zinc easily reacts with dilute sulphuric acid, producing hydrogen gas.

52. $HgCl_2$ is prepared by the reaction between

(a) HgS and aqua regia (b) Hg and heated chlorine

(c) Hg_2Cl_2 and heated mercury (d) Hg_2Cl_2 and dilute HCl

53. Which of the following statements are correct?

(a) Mercury (II) oxide exists in two different colours due to particle size.

(b) Mercury (II) oxide is thermally unstable.

(c) Mercurous ion is included in Group I among the analytical groups.

(d) The critical angle of mercury is 110°.

54. Which of the following are correctly matched?

(a) HgS $\longrightarrow$ Vermilion (b) $Hg_2Cl_2 \longrightarrow$ Laxative

(c) $HgCl_2 \longrightarrow$ Chlorophyll (d) $K_2HgI_4 \longrightarrow$ Nessler's reagent

55. Which of the following statements are correct?

(a) The first ionization energy of zinc is greater than that of mercury.

(b) The first ionization energy of zinc is less than that of mercury.

(c) Zn^{2+} is more reducing than Hg^{2+}.

(d) Zn is more reducing than Hg.

56. Zinc is the only metal in Group 12 which shows amphoteric properties, and is soluble in alkalis forming

(a) $Na_2[Zn(OH)_4]$ (b) $Na[Zn(OH)_3 \cdot (H_2O)_3]$

(c) $Na[Zn(OH)_3 \cdot H_2O]$ (d) $Na_4[Zn(OH)_6]$

57. Zinc can form four-coordinated complexes with various ligands, represented by the formulae

(a) $[Zn(CN)_4]^{4-}$ (b) $[Zn(CN)_4]^{2-}$

(c) $[Zn(NCS)_4]^{2+}$ (d) $[Zn(NH_3)_4]^{2+}$

58. Zinc is used in

(a) galvanization
(b) sherardizing
(c) dry batteries
(d) the preparation of alloys

59. Which of the following statements are correct for ZnO?

(a) It is an intrinsic semiconductor.
(b) It is an intrinsic superconductor.
(c) It shows grain boundary defects.
(d) When ZnO is heated with cobalt nitrate on a charcoal block in an oxidizing flame, it forms cobalt zincate, also known as Rinman's green.

60. For the equilibrium

$$Hg_2^{2+}(aq) \rightleftharpoons Hg\,(l) + Hg^{2+}\,(aq)$$

$$K_{eq} = \frac{[Hg^{2+}]}{[Hg_2^{2+}]} = 6 \times 10^3 \text{ at } 25°C$$

choose the correct options.

(a) The Hg (I) ion disproportionates to the Hg (II) ion and Hg.
(b) The addition of a Cl^- ion shifts the equilibrium to the right.
(c) The equilibrium is displaced to the right by the removal of the Hg^{2+} ion.
(d) The equilibrium is shifted to the left by the removal of the Hg^{2+} ion.

Answers

1. c	**2.** b	**3.** c	**4.** b	**5.** d
6. b	**7.** c	**8.** a	**9.** c	**10.** d
11. b	**12.** b	**13.** c	**14.** a	**15.** a
16. d	**17.** c	**18.** c	**19.** d	**20.** a
21. b	**22.** d	**23.** a	**24.** c	**25.** d
26. b	**27.** a	**28.** d	**29.** c	**30.** d
31. c	**32.** d	**33.** c	**34.** d	**35.** d
36. a	**37.** d	**38.** a	**39.** c	**40.** b
41. c	**42.** a	**43.** c	**44.** d	**45.** a
46. b	**47.** b	**48.** d	**49.** b	**50.** c
51. a, c, d	**52.** a, b, c	**53.** a, b, c	**54.** a, b	**55.** b, d
56. a, b, c	**57.** b, c, d	**58.** a, b, c, d	**59.** a, d	**60.** a, b, c

Hints to More Difficult Problems

2. The oxidation state of mercury in Hg_2^{2+} (mercurous ion) is +1.

11. It is made by the reaction between BaS and $ZnSO_4$.
$BaS + ZnSO_4 \longrightarrow BaSO_4 + ZnS$

16. $ZnSO_4 \cdot 7H_2O$ and $MgSO_4 \cdot 7H_2O$

17. $ZnSO_4 + Na_2HPO_4 + NH_3 \longrightarrow Zn(NH_4)PO_4 + Na_2SO_4$

$$2Zn(NH_4)PO_4 \xrightarrow{\Delta} Zn_2P_2O_7(s) + 2NH_3\uparrow + H_2O\uparrow$$

22. $HgCl_2$ is more polarized than the other compounds.

24. The size of the covalent radius increases from Zn to Hg, and the melting point decreases.

28. The smaller the ion, the greater is the tendency to form a hydrated salt.

34. $Hg \mid Hg_2Cl_2, Cl^-$, the cell reaction is

$$Hg_2Cl_2I(s) + 2e \longrightarrow 2Hg(l) + 2Cl^-$$

37. HgI_2 is the most covalent, and has the least tendency to hydrolyse.

40. $2HgCl_2 + SnCl_2 \longrightarrow Hg_2Cl_2 + SnCl_4$

$$Hg_2Cl_2 + SnCl_2 \longrightarrow 2Hg + SnCl_4$$

48. $ZnSO_4 + 4KCN \longrightarrow K_2[Zn(CN)_4] + K_2SO_4$

$$K_2[Zn(CN)_4] \longrightarrow 2K^+ + \underset{\text{(tetrahedral)}}{Zn(CN)_4^{2-}}$$

51. (a) $ZnSO_4 + 4NH_3 \longrightarrow [Zn(NH_3)_4]SO_4$

(c) $ZnSO_4 + H_2S \xrightarrow{NH_4Cl + NH_3} ZnS\downarrow$

(d) $Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$

60. (a) Hg_2^{2+} easily disproportionates to Hg and Hg^{2+} as indicated by the K_{eq} value. For options (b) and (c), consider Le Chatelier's principle.

❑

15

Iron

• *Type 1* •

Choose the correct option. Only one option is correct.

1. The chemical processes in the production of iron from haematite ore involve

(a) reduction
(b) oxidation
(c) reduction followed by oxidation
(d) oxidation followed by reduction

2. In the manufacture of iron, the principal reaction in the zone of heat absorption of the blast furnace is

(a) $2C(s) + O_2(g) \longrightarrow 2CO_2(g)$
(b) $CO_2(g) + C(s) \longrightarrow 2CO(g)$
(c) $2C(s) + O_2 \longrightarrow 2CO(g)$
(d) $3C(s) + O_2(g) \longrightarrow C_3O_2(g)$

3. In the extraction of iron, Fe_2O_3 is reduced by

(a) carbon (b) carbon dioxide
(c) carbon monoxide (d) calcium carbonate

4. Among the following, the maximum amount of carbon is present in

(a) pig iron (b) wrought iron
(c) steel (d) stainless steel

5. When hard steel is heated to bright redness and then allowed to cool slowly, it gets softened. The process is called

(a) annealing (b) hardening
(c) quenching (d) tempering

6. When mild steel is heated to a high temperature and suddenly cooled in water, it becomes hard and brittle. The process is called

(a) hardening (b) annealing

(c) quenching (d) tempering

7. Among the following salts of iron, which is the most unstable in an aqueous solution?

(a) $FeCl_3 \cdot 6H_2O$ (b) $Fe_2(SO_4)_3 \cdot 9H_2O$

(c) $K_4[Fe(CN)_6]$ (d) FeI_3

8. An $FeCl_3$ solution reacts with sodium hydroxide to produce

(a) $Fe_2O_3 \cdot nH_2O$ (b) Fe_3O_4

(c) FeO and $FeCl_3$ (d) Fe_2O_3 and FeO

9. In the manufacture of iron from haematite, limestone acts as a

(a) slag (b) flux

(c) matrix (d) reducing agent

10. Which of the following compounds of iron forms a dimer?

(a) $FeBr_2$ (b) FeI_3 (c) $FeCl_3$ (d) Fe_2O_3

11. Which of the following statements is correct?

(a) Molten slag and molten iron are drawn off through the same openings.

(b) Molten slag and molten iron are drawn off through separate openings.

(c) Slag floats on molten iron, thus protecting iron from reduction.

(d) Pig iron is soft and brittle.

12. The iron group contains

(a) six metals (b) three metals

(c) nine metals (d) eight metals

13. Iron reacts with P_4O_{10} in the presence of O_2 at a high temperature to produce

(a) $Fe_3(PO_4)_2$ (b) $FePO_4$

(c) Fe_3P (d) $Fe_3(PO_3)_2$

14. Iron is not attacked by

(a) concentrated NaOH (b) dilute NaOH

(c) dilute H_2SO_4 (d) steam

15. In $Fe_2(CO)_9$,

(a) two bridging CO groups are joined with two iron atoms

(b) five bridging CO groups are joined with two iron atoms

(c) three bridging CO groups are joined with two iron atoms
(d) one bridging CO group is joined with two iron atoms

16. The structure of $Fe(CO)_5$ is
(a) pentagonal bipyramidal
(b) irregular tetrahedral
(c) irregular octahedral
(d) trigonal bipyramidal

17. Which of the following is nonstoichiometric and metal deficient?
(a) FeO
(b) Fe_3O_4
(c) Fe_2O_3
(d) All of these

18. Which of the following has a cubic close-packed arrangement of O^{2-} ions with Fe^{2+} ions occupying all octahedral holes?
(a) $Fe(OH)_3$
(b) FeO
(c) $Fe(OH)_2$
(d) Fe_2O_3

19. $Fe(OH)_2$ dissolves in a concentrated NaOH solution giving a blue-green complex with the formula
(a) $Na_4[Fe_2(OH)_6]$
(b) $Na_2[Fe(OH)_6]$
(c) $Na_4[Fe(OH)_6]$
(d) $Na_4[Fe(OH)_4]$

20. Ferrocene is a compound of
(a) one Fe^{2+} and two $C_5H_5^-$ ions
(b) two Fe^{2+} and two $C_5H_6^-$ ions
(c) one Fe^{3+} and two $C_6H_5^-$ ions
(d) two Fe^{2+} and two $C_5H_5^-$ ions

21. Normally $FeCl_3 \cdot 6H_2O$ consists of
(a) *trans*-$[Fe(H_2O)_2Cl_2] \cdot Cl \cdot 4H_2O$
(b) *trans*-$[Fe(H_2O)_6Cl]Cl_2$
(c) *trans*-$[Fe(H_2O)_4Cl_2]Cl \cdot 2H_2O$
(d) *trans*-$[Fe(H_2O)_3Cl_2]Cl \cdot 3H_2O$

22. In concentrated HCl, $FeCl_3 \cdot 6H_2O$ forms an
(a) $[FeCl_6^{2-}]$ ion
(b) $[FeCl_4]^-$ ion
(c) $[FeCl_4]^+$ ion
(d) $[Fe(H_2O)_6]^{3+}$ ion

23. The rate of reaction of iron filings with oxygen may be increased by
(a) increasing the concentration of oxygen
(b) decreasing the amount of iron
(c) decreasing the pressure of oxygen
(d) lowering the temperature of iron

24. Which of the following methods is used to form a neutral ferric chloride solution?

(a) Adding an excess of NH_3 to an $FeCl_3$ solution
(b) Adding an excess of NaOH to an $FeCl_3$ solution
(c) Adding one to two drops of NH_3 to an $FeCl_3$ solution
(d) Adding dilute HCl to an $FeCl_3$ solution followed by the addition of an NaOH solution

25. The presence of Fe^{3+} ions is detected by the addition of SCN^- which gives a blood-red colour due to the formation of

(a) $[Fe(SCN)_3OH]^{2-}$ and some $[Fe(SCN)_3]^{2-}$
(b) $[Fe(SCN)_2(H_2O)_3]^{2+}$ and some $[Fe(SCN)_4]^-$
(c) $[Fe(SCN)_3(H_2O)_5]^{2+}$ and some $Fe(SCN)_3$
(d) $[Fe(SCN)(H_2O)_5]^{2+}$ and some $Fe(SCN)_3$ and $[Fe(SCN)_4]^-$

26. The addition of F^- to the blood-red solution of $[Fe(SCN)(H_2O)_5]^{2+}$ turns it colourless due to the formation of

(a) $[Fe(H_2O)_5F_3]$ (b) $[Fe(H_2O)_5F]^{2+}$
(c) $[FeF_6]^{3-}$ (d) $[FeF_4]^{-1}$

27. On fusion with Na_2CO_3, Fe_2O_3 gives

(a) Na_2FeO_4 (b) Fe_3O_4
(c) $NaFeO_2$ (d) Na_3FeO_3

28. A mixed oxide of iron, Fe_3O_4, is represented by

(a) $Fe_2^{II}Fe^{III}O_4$
(b) $Fe^{II}Fe_2^{III}O_4$ or $Fe^{III}(Fe^{II}Fe^{III})O_4$
(c) $Fe_2^{III}Fe^{II}O_4$
(d) $Fe^{III}Fe_2^{II}O_4$

29. On ignition to 1400°C, Fe_2O_3 gives black

(a) Fe_3O_4 (b) Fe (c) FeO (d) FeO_4^{2-}

30. If Cl_2 is passed into an alkaline solution of hydrated ferric oxide, a red-purple solution is formed containing the

(a) ferric ion Fe^{3+} (b) ferrate ion $Fe^{VI}O_4^{2-}$
(c) ferrite ion $Fe^{VI}O_4^{2-}$ (d) ferrate ion $Fe^{III}O_4^{5-}$

31. The electronic configuration of Fe^{3+} and Mn^{2+} are respectively

(a) $[Ar]\,3d^6\,4s^2$ and $[Ar]\,4d^6\,4s^2$
(b) $[Ar]\,3d^5\,4s^0$ and $[Ar]\,3d^5\,4s^1$

(c) $[Ar]\,3d^5\,4s^0$ and $[Ar]\,4d^5\,6s^0$

(d) $[Ar]\,3d^5\,4s^0$ and $[Ar]\,3d^5\,4s^0$

32. Which of the following statements is correct for $[Fe(H_2O)_5NO]^{2+}$, which is formed during the brown-ring test for the nitrate radical?

(a) The colour of the brown ring is not due to charge transfer spectra.

(b) In the complex mentioned, the oxidation number of iron is +2.

(c) The magnetic moment of iron in the complex mentioned is 3.9 Bohr magneton.

(d) The magnetic moment of iron in the complex mentioned is 2.83 Bohr magneton.

33. Among the following compounds, which is thermally the most stable?

(a) FeO (b) Fe_2O_3 (c) Fe_3O_4 (d) $FeCO_3$

34. In the ferrocene $[Fe(C_5H_5)_2]$ molecule the bonding is regarded as π-bonding involving the lateral overlap of

(a) the d_{xz} and d_{yz} orbitals on Fe with a delocalized aromatic orbital from each cyclopentadienyl ring

(b) p_x and p_y orbitals on Fe with a delocalized aromatic orbital from each cyclopentadienyl ring

(c) d_{xz} and d_{yz} orbitals on Fe with a localized aromatic orbital from each cyclopentadienyl ring

(d) d_{z^2} orbitals on Fe with a delocalized aromatic orbital from each cyclopentadienyl ring

35. The alloy nichrome contains

(a) Ni, Cr, Fe and Mn (b) Cr, Ni, Cu and Zn

(c) Ni, Cr, Fe and Zn (d) Ni, Cr, Fe and C

36. The concentration of chromite ($FeCrO_4$) is carried out by

(a) gravity separation (b) froth floation

(c) magnetic separation (d) roasting

37. The densities of Pb, Fe and Al are in the order

(a) Pb > Fe > Al (b) Fe > Al > Pb

(c) Pb > Al > Fe (d) Al > Fe > Pb

38. Concentrated nitric acid passivates iron due to the

(a) formation of $Fe(NO_3)_2$, which does not react with iron, on the surface of the iron

(b) formation of a protective coating of the oxide of iron which does not react with nitric acid, on the surface of the iron

(c) formation of a stable complex on the surface of the iron

(d) decomposition of nitric acid into NO_2 and O_2

39. On strong heating, $Fe_2(SO_4)_3$ gives
(a) Fe_2O_3 and SO_2 (b) FeO and SO_3
(c) Fe_2O_3 and SO_3 (d) Fe_2O_3 and SO_2

40. Which of the following is used to estimate iron volumetrically using a $KMnO_4$ or a $K_2Cr_2O_7$ solution?
(a) $FeCl_3 \cdot 6H_2O$ (b) Fe_3O_4
(c) $Fe_2(SO_4)_3 \cdot 9H_2O$ (d) $FeSO_4(NH_4)_2SO_4 \cdot 6H_2O$

41. Ferrous and ferric salts can be best distinguished from each other by using the reagent
(a) $Fe(SCN)_3$ (b) NH_4CNO
(c) $K_4[Fe(CN)_6]$ (d) dilute HNO_3

42. Acidified $KMnO_4$ is decolourized by
(a) the ferric ammonium alum
(b) Mohr's salt
(c) haematite
(d) a neutral ferric chloride solution

43. On strong heating, which of the following produces a mixture SO_2 and SO_3?
(a) $Fe_2(SO_4)_3 \cdot 9H_2O$
(b) $(NH_4)_2SO_4 \cdot Fe_2(SO_4)_3 \cdot 24H_2O$
(c) $FeSO_4 \cdot 7H_2O$
(d) FeS_2

44. $FeSO_4$ reacts with $K_3[Fe(CN)_6]$ to give a blue precipitate known as Turnbull's blue. This precipitate is one of
(a) $K\,Fe^{II}[Fe^{II}(CN)_6]$ (b) $K\,Fe^{III}[Fe^{III}(CN)_6]$
(c) $K\,Fe^{III}[Fe^{II}(CN)_6]$ (d) $K\,Fe^{II}[Fe^{III}(CN)_6]$

45. $FeCl_3$ reacts with $K_4[Fe(CN)_6]$ to give a blue precipitate known as Prussian blue. Prussian blue is
(a) $Fe_4^{III}[Fe^{III}(CN)_6]$ (b) $Fe_4^{II}[Fe^{II}(CN)_6]$
(c) $K\,Fe^{III}[Fe^{II}(CN)_6]$ (d) $K\,Fe^{II}[Fe^{IV}(CN)_6]$

46. When heated with concentrated H_2SO_4, $K_4[Fe(CN)_6]$ gives
(a) $(CN)_2$ and CO_2 (b) $(CN)_2$ and CO
(c) CO (d) CO_2

47. Rusting of iron is

(a) an electrochemical process (b) an electroanalytical process
(c) a photochemical process (d) all of these

48. Rusting of iron is prevented by

(a) galvanizing
(b) electroplating the iron with a thin layer of tin
(c) converting the outer layer of the iron into iron phosphate
(d) all of these

49. In which of the following reactions is potassium ferrocyanide produced?

(a) The reaction between $K_3[Fe(CN)_6]$ and an excess of $FeSO_4$
(b) The reaction between $FeSO_4$ and an excess of KCN
(c) The reaction between $Fe_2(SO_4)_3$ and an excess of KCN
(d) The reaction between Fe_2O_3 and an excess of KCN

50. In an aqueous solution, it is easier to oxidize

(a) $[Fe^{II}(CN)_6]^{4-}$ ions than $[Fe^{III}(CN)_6]^{3-}$ ions
(b) $[Fe^{II}(CN)_6]^{4-}$ ions than $Fe^{IV}O_4^{4-}$ ions
(c) $[Fe^{II}(H_2O)_6]^{2+}$ ions than $[Fe^{III}(H_2O)_6]^{3+}$ ions
(d) $[Fe^{II}(CN)_6]^{4-}$ ions than $[Fe^{III}(H_2O)_6]^{3+}$ ions

• Type 2 •

Choose the correct options. More than one option is correct.

51. Which of the following statements are correct?

(a) The process of producing a hard coating of iron nitride on the surface of steel is called nitriding.
(b) The process of producing a thin coating of hardened steel on the surface of mild steel is called hardening.
(c) Quenched steel is produced by heating steel to redness and allowing it to cool slowly.
(d) Stainless steel is produced by heating wrought iron in molten chromium.

52. Which of the following statements are correct?

(a) Cast iron cannot be permanently magnetized.
(b) Steel cannot be permanently magnetized.
(c) Steel can be permanently magnetized.
(d) Spiegeleisen is an alloy of iron, zinc and antimony.

53. By which of the following reactions can Fe^{III} be detected?

(a) $FeCl_3 + 3NH_4SCN \longrightarrow Fe(SCN)_3 + 3NH_4Cl$

(b) $FeCl_3 + K_3[Fe(CN)_6] \longrightarrow K\,Fe[Fe(CN)_6] + 2KCl + \frac{1}{2}Cl_2$

(c) $FeCl_3 + K_4[Fe(CN)_6] \longrightarrow K\,Fe[Fe(CN)_6] + 3KCl$

(d) $FeCl_3 + 3KSCN \longrightarrow Fe(SCN)_3 + 3KCl$

54. In which of the following does iron have an oxidation state of zero?

(a) $[Fe(H_2O)_5NO]SO_4$ (b) $Fe(CO)_5$

(c) $Fe(CNS)_3$ (d) $Fe_2(CO)_9$

55. Which of the following reactions are used to prepare $K_4[Fe(CN)_6]$?

(a) $FeSO_4 + 6KCN \longrightarrow K_4[Fe(CN)_6] + 2K_2SO_4$

(b) $2K_3[Fe(CN)_6] + H_2 + 2KOH \longrightarrow 2K_4[Fe(CN)_6] + 2H_2O$

(c) $2K_3[Fe(CN)_6] + K_2SO_4 + 2H_2O \longrightarrow 2K_4[Fe(CN)_6] + H_2SO_4 + H_2O_2$

(d) $2K_3[Fe(CN)_6] + 2KOH + H_2O_2 \longrightarrow 2K_4[Fe(CN)_6] + 2H_2O + O_2$

56. Which of the following statements are correct?

(a) Potassium hexacyanoferrate (III) is orange while potassium hexacyanoferrate (II) is yellow.

(b) Fe (II) and Fe (III) form complexes with the CN^- ion but not with NH_3.

(c) Ferric salts are more stable than ferrous salts.

(d) The ferric ammonium alum is a complex salt.

57. Which of the following statements are correct?

(a) All Fe^{2+} salts are pale green.

(b) In an aqueous solution, the Fe^{2+} ion can readily be oxidized to the Fe^{3+} ion even by atmospheric O_2.

(c) Fe^{2+} salts decolourize an acidified $KMnO_4$ solution.

(d) Fe^{2+} salts turn acidified $K_2Cr_2O_7$ green.

58. Which of the following statements are correct?

(a) Ferric salts do not react with NO.

(b) The formula of sodium nitroprusside is $Na_2[Fe(CN)_5NO]$.

(c) Turnbull's blue is paler than Prussian blue.

(d) The structure of the $[Fe(CN)_6]^{4-}$ ion is due to d^2sp^3 hybridization.

59. Which of the following statements are correct?

(a) $[Fe(CN)_6]^{4-}$ is diamagnetic but $[Fe(CN)_6]^{3-}$ is paramagnetic.

(b) Fe^{3+} ions always form tetrahedral complexes.

(c) In a compound with an octahedral structure, the d_{xy} and d_{yz} orbitals of a metal ion should be vacant.

(d) $[Fe(H_2O)_6]^{3+}$ is more paramagnetic than $[Fe(CN)_6]^{3-}$.

60. Which of the following statements are correct?

(a) The element present in invar are Fe, Co and Ni.

(b) $[Fe(CN)_6]^{4-}$ is a low-spin complex while $[Fe(H_2O)_6]^{3+}$ is a high-spin complex.

(c) Fe^{3+} usually forms octahedral complexes that have low spin.

(d) In the octahedral geometry of a metallic compound, the $d_{x^2-y^2}$ and d_z^2 orbitals of the metal should be vacant.

Answers

1. c	**2.** b	**3.** c	**4.** a	**5.** a
6. c	**7.** d	**8.** a	**9.** b	**10.** c
11. b	**12.** c	**13.** a	**14.** b	**15.** c
16. d	**17.** d	**18.** b	**19.** c	**20.** a
21. c	**22.** b	**23.** a	**24.** c	**25.** d
26. c	**27.** c	**28.** b	**29.** a	**30.** b
31. d	**32.** c	**33.** b	**34.** c	**35.** d
36. c	**37.** a	**38.** b	**39.** c	**40.** d
41. c	**42.** b	**43.** c	**44.** d	**45.** c
46. c	**47.** a	**48.** d	**49.** b	**50.** a
51. a, b	**52.** a, c	**53.** a, c, d	**54.** b, d	**55.** a, d
56. a, b, c	**57.** a, b, c, d	**58.** a, b, c, d	**59.** a, d	**60.** a, b, c, d

Hints to More Difficult Problems

1. In the following formulae, the superscripts denotes oxidation number

$$3\overset{+3}{Fe_2}O_3 + CO \xrightarrow{400°C} 2\overset{+8/3}{Fe_3}O_4 + CO_2$$

$$\overset{+8/3}{Fe_3}O_4 + CO \xrightarrow{400°C} 2\overset{+2}{Fe}O + CO_2$$

$$\overset{+2}{Fe}O + CO \xrightarrow{800°C} \overset{0}{Fe} + CO_2$$

$$2\overset{+2}{C}O \longrightarrow C + \overset{+4}{C}O_2$$

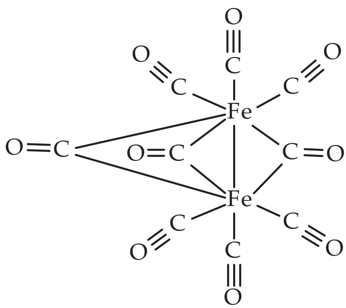
$$\overset{0}{C} + O_2 \longrightarrow \overset{+4}{C}O_2$$

2. The reaction is endothermic.

3. See the answer to Q. 1.

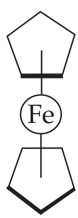
7. Fe^{3+} oxidizes I^- to I_2.

15.



17. The fact that they are nonstoichiometric is related to their structures, which are similar. The ccp structures differ only in the arrangement of Fe^{2+} and Fe^{3+} in the holes in the octahedral and tetrahedral crystals.

20.



28. Fe_3O_4 is an inverse (2 : 3) spinel represented by $B(AB)O_4$. All spinel structures have a ccp array of anions.

31. $Fe(Z = 26) = [Ar]3d^6 4s^2$

$Fe^{3+} = [Ar]3d^5$

$Mn(Z = 25) = [Ar]3d^5 4s^2$

$Mn^{2+} = [Ar]3d^5$

37. Density increases with molar mass.

40. $MnO_4^- + 8H^+ + 5Fe^{2+} \longrightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$

$Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \longrightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$

The Fe^{2+} ion is produced from $FeSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$.

43. $FeSO_4 \cdot 7H_2O \xrightarrow{\Delta} FeSO_4 + 7H_2O$

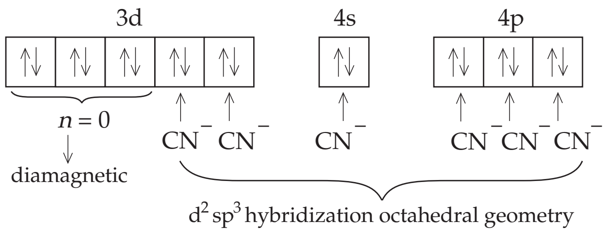
$2FeSO_4 \xrightarrow{\Delta} Fe_2O_3 + SO_2\uparrow + SO_3\uparrow$

54. (a) In $Fe(CO)_5$, $x + 5 \times 0 = 0 \Rightarrow x = 0$.

(b) In $Fe_2(CO)_9$, $2x + 9 \times 0 = 0 \Rightarrow x = 0$.

Here x is the oxidation state of iron.

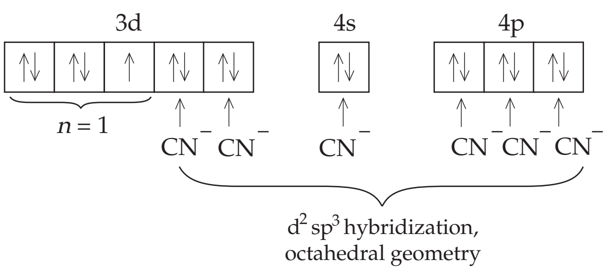
59. (a) In $[Fe(CN)_6]^{4-}$ the electronic structure is as follows.



$\mu_{spin} = \sqrt{n(n+2)}$ BM

$\mu_{spin} = 0$

The electronic structure of $Fe(CN)_6^{3-}$ is as follows.

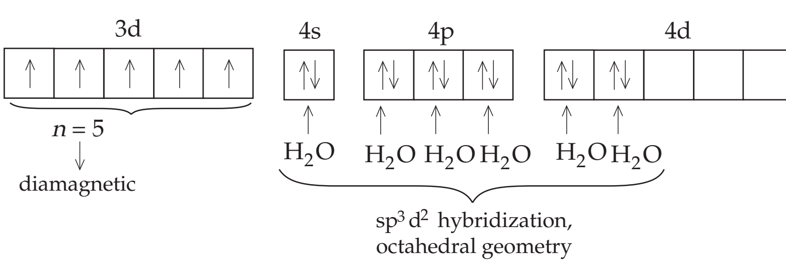


$\mu_{spin} = \sqrt{n(n+2)} = \sqrt{3} = 1.73$ BM

Therefore, $[Fe(CN)_6]^{4-}$ is diamagnetic and $[Fe(CN)_6]^{3-}$ paramagnetic.

(d) In $[Fe(CN)_6]^{3-}$, CN^- is a strong ligand. It forces electrons to pair up. But in $[Fe(H_2O)_6]^{3+}$, H_2O is a weak ligand and cannot force electrons to pair up. So $n = 5$, and hence it is more paramagnetic than $[Fe(CN)_6]^{3-}$.

The electronic structure of $[Fe(H_2O)_6]^{3+}$ is as follows.



Here $n = 5$.

$\mu_{spin} = \sqrt{n(n+2)} = \sqrt{5(5+2)} = 5.92$ BM

❑

16

Coordination Chemistry

• *Type 1* •

Choose the correct option. Only one option is correct.

1. Which of the given statements is not true for the following reaction?

$$[Cu(H_2O)_4]^{2+} + 4NH_3 \rightleftharpoons [Cu(NH_3)_4]^{2+} + 4H_2O$$

(a) It is a ligand-substitution reaction.

(b) NH_3 is a relatively strong-field ligand while H_2O is a weak-field ligand.

(c) During the reaction, there is a change in colour from light blue to dark blue.

(d) $[Cu(NH_3)_4]^{2+}$ has a tetrahedral structure, and is paramagnetic.

2. Which of the following is a hexadentate ligand?

(a) 2,2-Dipyridyl

(b) Ethylenediamine

(c) Ethylenediaminetetracetate ion

(d) Biphenyl

3. Dimethyl glyoxime is an example of a

(a) monodentate ligand (b) bidentate ligand

(c) tridentate ligand (d) hexadentate ligand

4. Ferrocene is

(a) bis (cyclopentadienyl) iron (II)

(b) dicyclopentadienyl iron (0)

(c) dicylopentadienyl iron (III)

(d) bis (cyclopentyl) iron (II)

5. The IUPAC name of the complex $[Ni(C_4H_7O_2N_2)_2]$ formed from the reaction of Ni^{2+} with dimethyl glyoxime is

(a) bis (methyl gloxal) nickel (II)
(b) bis (dimethyl oxime) nickelate (IV)
(c) bis (2,3-butanediol dioximato) nickel (II)
(d) bis (2,3-butanedione dioximato) nickel (II)

6. Which of the following complex ions obeys Sidwick's Effective Atomic Number (EAN) rule?

(a) $[Fe(CN)_6]^{3-}$ (b) $[Cu(CN)_4]^{3-}$
(c) $[Cr(NH_3)_6]^{3+}$ (d) $[Ni(en)_3]^{2+}$

7. The effective atomic number for the complex ion $[Pd(NH_3)_6]^{4+}$ is
(a) 54 (b) 86
(c) 36 (d) 50

8. Which of the following complex ions violates the EAN rule?

(a) $[Fe(CO)_5]$ (b) $[Cr(NH_3)_6]^{3+}$
(c) $[Fe(CN)_6]^{4-}$ (d) $[Mn(H_2O)_6]^{2+}$

9. The effective atomic number for the complex ion $[Ni(CN)_4]^{2-}$ is
(a) 36 (b) 86
(c) 34 (d) 18

10. The IUPAC name for the complex compound $Li[AlH_4]$ is
(a) lithium aluminium hydride
(b) hydrido aluminium lithium (III)
(c) lithium tetrahydridoaluminate (III)
(d) lithium tetrahydridoaluminate (I)

11. The IUPAC name for the coordination compound $[CuCl_2(CH_3NH_2)_2]$ is
(a) dichlorobis (dimethylamine) copper (II)
(b) dichlorobis (methylamine) copper (II)
(c) dimethylamine copper (II) chloride
(d) bis (dimethylamine) copper (II) chloride

12. The IUPAC name for $Ba[BrF_4]_2$ is
(a) barium bromofluorite (III)
(b) bis (tetrafluorobromium) barium (II)
(c) barium bis (tetrafluorobromate) (V)
(d) barium tetrafluorobromate (III)

13. The IUPAC name for the coordination compound $Na_3[Ag(S_2O_3)_2]$ is
(a) sodium bis (argentothiosulphate) (I)
(b) sodium bis (thiosulphato) argentate (I)

(c) sodium silver hyposulphate (I)
(d) sodium silver thiosulphate (I)

14. The oxidation number of Co in $[Co(en)_3]_2(SO_4)_3$ is
(a) +2 (b) +4
(c) +3 (d) +6

15. The IUPAC name for $K[SbCl_5C_6H_5]$ is
(a) luteroantimonate (V)
(b) potassium pentachloro (phenyl) antimonate (V)
(c) potassium phenylchloroantimonate (V)
(d) potassium benzalantimony (III) chloride

16. The IUPAC name for $K_2[Cr(CN)_2O_2(O_2)NH_3]$ is
(a) potassium amminedicyanodioxoperoxochromate (VI)
(b) potassium amminedicyanotetroxochromium (III)
(c) potassium amminedicyanochromate (IV)
(d) potassium amminocyanodiperoxochromate (VI)

17. The structures of $Ni(CO)_4$ and $Ni(PPh_3)_2Cl_2$ are
(a) square planar
(b) tetrahedral and square planar respectively
(c) tetrahedral
(d) square planar and tetrahedral respectively

18. The hybridization states of the central atoms in the complexes $Fe(CN)_6^{3-}$, $Fe(CN)_6^{4-}$ and $Co(NO_2)_6^{3-}$ are
(a) d^2sp^3, sp^3 and d^4s^2 respectively
(b) d^2sp^3, sp^3d and sp^3d^2 respectively
(c) d^2sp^3, sp^3d^2 and dsp^2 respectively
(d) all d^2sp^3

19. Which of the following complexes is not easily oxidized?
(a) $Ni(CO)_4$ (b) $[Mn(CN)_6]^{5-}$
(c) $Cr(CO)_4$ (d) $Fe(CO)_5$

20. Among the following complexes, which is the most stable?
(a) $[Ni(CN)_4]^{4-}$ (b) $[Pd(CN)_4]^{4-}$
(c) $[Ni(CN)_4]^{3-}$ (d) $[Fe(CO)_5]$

21. Which of the following is colourless?
(a) $[Ti(H_2O)_6]^{3+}$ (b) $[Ti(NO_3)_4]$
(c) $[Cr(NH_3)_6]^{3+}$ (d) $[Fe(CN)_6]^{4-}$

22. The oxidation number and coordination number of Pt in the coordination compound $Na[Pt(C_2H_4)Cl_3]$ are respectively

(a) 4 and 4 (b) 4 and 5

(c) 2 and 3 (d) 2 and 4

23. The magnetic moment of a complex ion is 1.73 BM. The ion is

(a) $[Co(NH_3)_6]^{2+}$ (b) $[MnF_6]^{3-}$

(c) $[Fe(CN)_5NO^+]$ (d) $[Mn(CN)_6]^{4-}$

24. Which of the following is not paramagnetic?

(a) $[Cu(NH_3)_4]SO_4$ (b) $[Mn(H_2O)_6]^{2+}$

(c) $[Ag(NH_3)_2]$ Cl (d) $[NiCl_4]^{2-}$

25. The IUPAC name for $[Co(NH_3)_6]$ $[Cr(CN)_6]$ is

(a) hexaammine cobalt (III) hexacyanochromate (III)

(b) hexacyanochromium cobalt hexaammine (VI)

(c) hexaammine cobalt (III) hexacyanochromium (VI)

(d) hexacyanochromium (III) hexaammine cobalt (III)

26. The IUPAC name for $[Be_4O(CH_3COO)_6]$ is

(a) basic beryllium acetate (II)

(b) hexa-μ-hexakis (acetato) beryllium (II)

(c) hexa-μ-acetato (O, O′)-μ_4-oxo-tetraberyllium (II)

(d) hexaacetato-μ-oxo-beryllate (II)

27. The IUPAC name for $[Co(NCS)(NH_3)_5]Cl_2$ is

(a) pentaammine (thiocyanato-N) cobalt (III) chloride

(b) pentaammine (thiocyanato-S) cobalt (III) chloride

(c) pentaammine (isothiocyanato-N, S) cobalt (III) chloride

(d) pentaammine (mercapto-N) cobalt (III) chloride

28. The IUPAC name for $K_2[OsCl_5N]$ is

(a) potassium pentachloroazidoosmate (VIII)

(b) potassium pentachloroazoosmate (VI)

(c) potassium pentachloronitridoosmate (VI)

(d) potassium nitroosmate (III)

29. Among the following aquated metal ions, which has the highest degree of paramagnetism?

(a) $[Cr(H_2O)_6]^{3+}$ (b) $[Fe(H_2O)_6]^{2+}$

(c) $[Cu(H_2O)_6]^{2+}$ (d) $[Zn(H_2O)_2]^{2+}$

30. Which of the following is a low-spin (spin-paired) complex?

(a) $[Co(NH_3)_6]^{2+}$ (b) $[Fe(C_2O_4)_3]^{3-}$

(c) $[Ni(NH_3)_6]^{2+}$ (b) $[Co(NH_3)_6]^{3+}$

31. Which of the following is a high-spin (spin-free) complex?

(a) $[Co(NH_3)_6]^{3+}$ (b) $Fe(CN)_6]^{4-}$

(c) $[CoF_6]^{3-}$ (d) $[Zn(NH_3)_6]^{2+}$

32. The ferrous ion in a given sample is detected by the formation of a white precipitate on the addition of a potassium ferrocyanide solution to it. The precipitate has the constitutional formula

(a) $K_2Fe^{II}[Fe^{II}(CN)_6]$ (b) $K_2Fe^{III}[Fe(CN)_6]$

(c) $K\,Fe^{III}[Fe^{II}(CN)_6]$ (d) $KFe^{II}[Fe^{III}(CN)_6]$

33. The formula of the complex potassium trichloro (ethylene) platinate (II) is

(a) $K[PtCl_3(C_2H_4)]$ (b) $K_2[PtCl_3(C_2H_4)_3]$

(c) $K_4[PtCl_3(C_2H_4)]$ (d) $K_3[Pt_2Cl_3(C_2H_4)_3]$

34. The formula of the complex sodium hydridotrimethoxyborate (III) is

(a) $Na_4[BH_2(OCH_3)_3]$ (b) $Na_2[BH(OCH_3)_3]$

(c) $Na[BH_2(OCH_3)_3]$ (d) $Na[BH(OCH_3)_3]$

35. The formula of the complex triamminetri (nitrito-N) cobalt (III) is

(a) $[Co(ONO_2)_3(NH_3)_3]$ (b) $[Co(NO_2)_3(NH_3)_3]$

(c) $[Co(ONO)_3(NH_3)_3]$ (d) $[Co(NO_2)(NH_3)_3]$

36. The IUPAC name for $[(CO_5)Mn—Mn(CO)_5]$ is

(a) bis (pentacarbonylmanganate) (VIII)
(b) bis (pentacarbonyl dimanganese)
(c) bis (pentacarbonyl manganese)
(d) decacarbonyldimanganate (VIII)

37. The IUPAC name for $[Pt(py)_4][PtCl_4]$ is

(a) tetrakis (pyridine platinum (II) tetrachloroplatinate (II)
(b) tetrapyridine tetrachlorodiplatinum (IV)
(c) tetrachlorotetrapyridine diplatinum (II)
(d) tetrakis (pyridine) platinum (IV) tetrachloroplatinum (IV)

38. The IUPAC name for $[(NH_3)_5Cr–OH–Cr(NH_3)_5]^{5+}$ is

(a) μ-hydroxo-bis (pentaammine dichromium) (5+) ion

(b) μ-hydroxo-bis (decaammine dichromium (5+) ion

(c) μ-hydroxo-bis (octaammine chromium) (5+) ion
(d) μ-hydroxo-bis (pentammine chromium) (III)

39. The IUPAC name for $[Co(ONO)(NH_3)_5]SO_4$ is
(a) pentaammine (nitrito-O) cobalt (III) sulphate
(b) pentaammine (nitroso-N) cobalt (III) sulphate
(c) pentaammine (nitro-O) cobalt (III) sulphate
(d) pentaammine (nitroyl-O) cobalt (III) sulphate

40. The IUPAC name for $[(CO)_3Fe(CO)_3Fe(CO)_3]$ is
(a) tri-μ-hexacarbonyl iron (II)
(b) tri-μ-carbonyl-bis (tricarbonyl iron)
(c) tri-μ-carbonyl-bis (tricarbonyl di-iron)
(d) tri-μ-manocarbonyl iron (III)

41. The hybridization states of the central atoms in the complex ions $[FeF_6]^{3-}$, $[Fe(H_2O)_6]^{3+}$ and $[Ni(NH_3)_6]^{2+}$ are
(a) $3s4p^3 4d^2$, $4d3s4d^2$ and $4d^4 5s^2$ respectively
(b) all $3d^2 4s4p^3$
(c) all $4s4p^3 4d^2$
(d) $3s4p^3 4d^2$, $4d3s4p^3$ and $4p^4 5d^2$ respectively

42. The formation of the complex ion $[Co(NH_3)_6]^{3+}$ involves the sp^3d^2 hybridization of Co^{3+}. Therefore the complex ion should have
(a) an octahedral geometry
(b) a tetrahedral geometry
(c) a square-planar geometry
(d) a square-antiprismic geometry

43. $[Co(NH_3)_5NO_3]SO_4$ and $[Co(NH)_5SO_4]NO_3$ exhibit
(a) coordinate isomerism (b) linkage isomerism
(c) ionization isomerism (d) optical isomerism

44. What type of isomerism do the forms $[Co(NH_3)_6][Cr(CN)_6]$ and $[Cr(NH_3)_6][Co(CN)_6]$ exhibit?
(a) Coordination position isomerism
(b) Coordination isomerism
(c) Ligand isomerism
(d) Polymerization isomerism

45. How many isomers can $CrCl_3 \cdot 6H_2O$ have?
(a) Six (b) Four
(c) Three (d) Two

46. Which of the following will have three isomeric forms?

$[Cr(NO_3)_3(NH_3)_3]$ (I), $K_3[Co(C_2O_4)_3]$ (II), $K_3[Co(C_2O_4)_2Cl_2]$ (III) and $[Co(en)_2ClBr]$ (IV) where en = ethylene diamine.

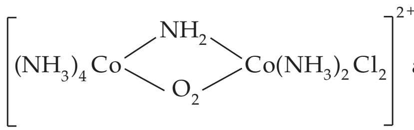
(a) IV and III (b) IV and I
(c) III and II (d) I and II

47. Which among the following pairs of complex compounds is an example of linkage isomerism?

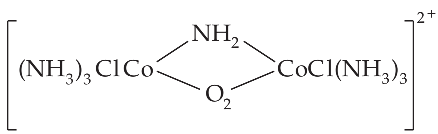
(a) $[PtCl_2(NH_3)_4]Br_2$ and $[PtBr_2(NH_3)_4]Cl_2$

(b) $[Cu(NH_3)_4][PtCl_4]$ and $[CuCl_4][Pt(NH_3)_4]$

(c)



and



(d) $[Co(NO_2)(NH_3)_5]Cl$ and $[Co(ONO)(NH_3)_5]Cl_2$

48. Which of the following statements is correct?

(a) The $[Ni(CN)_4]^{2-}$ ion has tetrahedral geometry and is diamagnetic.
(b) The $[Ni(CN)_4]^{2-}$ ion has a square-planar geometry and is paramagnetic.
(c) The $[Ni(CN)_4]^{2-}$ ion has a square-planar geometry and is diamagnetic.
(d) The $[Cu(NH_3)_4]^{2+}$ ion has a tetrahedral geometry and is diamagnetic.

49. Which of the following statements is correct?

(a) Most four-coordinated complexes of Ni^{2+} ions are square planar rather than tetrahedral.
(b) The $[Fe(H_2O)_6]^{3+}$ ion is more paramagnetic than the $[Fe(CN)_6]^{3-}$ ion.
(c) Square-planar complexes are more stable than octahedral complexes.
(d) The $[Fe(CN)_6]^{4-}$ ion is paramagnetic but $[Fe(CN)_6]^{3-}$ ion is diamagnetic.

50. Which of the following statements is true?

(a) $Ni(CO)_4$ and $[NiCl_4]^{2-}$ are diamagnetic, and $[Ni(CN)_4]^{2-}$ is paramagnetic.

(b) $[NiCl_4]^{2-}$ and $[Ni(CN)_4]^{2-}$ are diamagnetic, and $[Ni(CO)_4]$ is paramagnetic.

(c) $[Ni(CO)_4]$ and $[Ni(CN)_4]^{2-}$ are diamagnetic, and $[NiCl_4]^{2-}$ is paramagnetic.

(d) $[Ni(CO)_4]$ is diamagnetic, and $[NiCl_4]^{2-}$ and $[Ni(CN)_4]^{2-}$ are paramagnetic.

51. How many geometrical isomers are possible for the square-planar complex $[Pt(NO_2)(py)(NH_3)(NH_2OH)]NO_2$?

(a) Four
(b) Five
(c) Eight
(d) Three

52. Tetrahedral complexes of the types Ma_4 and Ma_3b (where M stands for a metal, and a and b are achiral ligands) do not show optical isomerism because they have

(a) a C_n axis of symmetry
(b) a plane of symmetry and hence are achiral
(c) a centre of symmetry
(d) nonsuperimposable mirror images

53. Which of the following types of octahedral complexes exhibit geometrical isomerism (M stands for a metal, and a and b are achiral ligands)?

(a) $[Ma_6]$
(b) $[Ma_5b]$
(c) $[M(aa)_3]$
(d) $[Ma_4b_2]$

54. Which of the following types of square-planar complexes can show geometrical isomerism (M stands for a metal, and a and b are achiral ligands)?

(a) Ma_4
(b) Ma_3b
(c) Ma_2b_2
(d) Mab_3

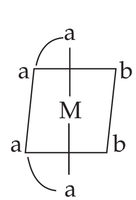
55. The tris (ethylenediamine) cobalt (III) cation, $[Co(en)_3]^{3+}$, can have

(a) three stereoisomers, all chiral and optically active
(b) two chiral stereoisomers (enantiomers)
(c) three stereoisomers, all achiral
(d) two stereoisomers, both achiral

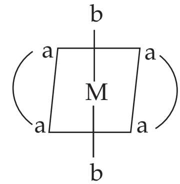
56. Which of the following statements is correct?

(a) $[Co(NH_3)_6]^{2+}$ is oxidized to diamagnetic $[Co(NH_3)_6]^{3+}$ by the oxygen in air.
(b) $[Fe(CN)_6]^{3-}$ is stable but $[FeF_6]^{3-}$ is unstable.
(c) $[Co(H_2O)_6]^{2+}$ is easily oxidized to $[Co(H_2O)_6]^{3+}$.
(d) None of these

57. Which of the following statements is correct regarding the chirality (optical isomerism) of the cis and trans isomers of the type $M(aa)_2b_2$ (M stands for a metal, a and b are achiral ligands, and aa is a bidentate ligand)?



cis



trans

(a) The trans form is achiral and optically inactive while the cis form is chiral and exists in two enantiomeric forms.

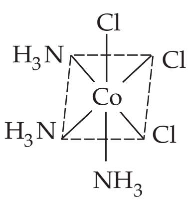
(b) The cis as well as the trans form are achiral and optically inactive.

(c) The trans form is chiral and exists in two enantiomeric forms while the cis form is achiral and optically inactive.

(d) The cis as well as the trans form are chiral, and each of them exists in two enantiomeric forms.

58. Which of the following pairs of structures represents facial and meridianal isomers (geometrical isomers) respectively?

(a)



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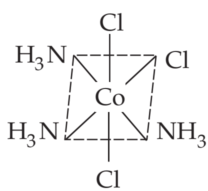
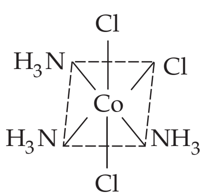


(b)



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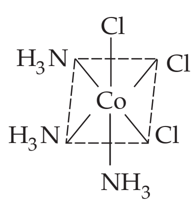
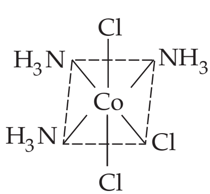
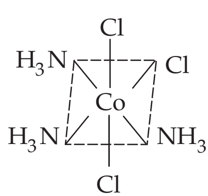
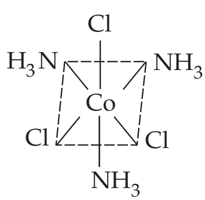
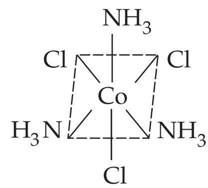


(c)



and



(d)  and 

59. Which of the following statements is correct regarding the stereoisomerism of the complexes referred to (M stands for a metal, and a, b, c, and d are achiral ligands)?

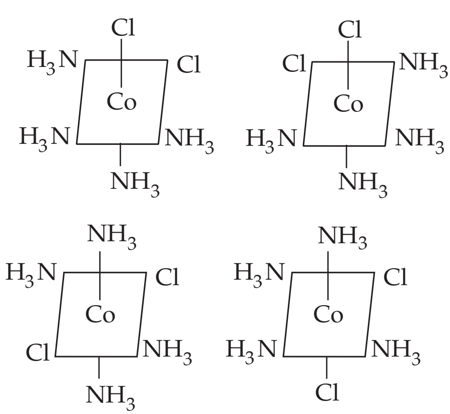
(a) In the cis and trans isomers of the octahedral complex $M(a_2b_4)$, the two ligands occupy the positions 1, 2 and 1, 6 respectively.

(b) The facial and meridianal isomers of the octahedral complex $M(a_3b_3)$ have three identical ligands (a or b) at positions 1,2,3- and 1,2,6-respectively.

(c) The octahedral complex $M(abcd\ \widehat{ee})$ where $\widehat{ee}$ is a bidentate ligand should have twelve stereoisomers.

(d) The facial as well as the meridianal isomers of the octahedral complex of the type Ma_3b_3 are optically active.

60. Consider the following arrangements of the octahedral complex ion $[Co(NH_3)_4Cl_2]^+$.



Which of the following statements is incorrect?

(a) I and II are enantiomers.

(b) II and III are cis and trans isomers respectively.

(c) III and IV are trans and cis isomers respectively.

(d) II and IV are identical structures.

• Type 2 •

Choose the correct options. More than one option is correct.

61. Which of the following will produce a white precipitate upon reacting with $AgNO_3$?

(a) $[Co(NH_3)_6]Cl_3$ (b) $Co(NH_3)_3Cl_3]$

(c) $K_2[Pt(en)_2Cl_2]$ (d) $[Fe(en)_3]Cl_3$

62. In which of the following does the central atom exhibit an oxidation state of +2?

(a) $K_2[Ni(CN)_4]$ (b) $K_4[Fe(CN)_6]$

(c) $[Fe(C_2O_4)_3]^{3-}$ (d) $[Cu(NH_3)_4]^{2+}$

63. In which of the following are the chemical formula and the name correctly matched?

(a) $K[Pt(NH_3)Cl_5]$—potassium amminepentachloroplatinate (IV)

(b) $[Ag(CN)_2]^-$—dicyanoargentate (I) ion

(c) $K_3[Cr(C_2O_4)_3]$—potassium trioxalatochromate (III)

(d) $Na_2[Ni(EDTA)]$—Sodium ethylenediaminetetra-acetonickel (I)

64. Which of the following are π-bonded organometallic compounds?

(a) Ferrocene (b) Diethyl zinc

(c) Ethylmagnesium iodide (d) Dibenzene chromium

65. Which of the following exhibit geometrical isomerism (M stands for a metal, and a and b are achiral ligands)?

(a) Ma_2b_2 (b) Ma_4b_2 (c) Ma_5b (d) Ma_6

Answers

1. d	**2.** c	**3.** b	**4.** b	**5.** d
6. b	**7.** a	**8.** d	**9.** c	**10.** c
11. b	**12.** d	**13.** b	**14.** c	**15.** b
16. a	**17.** c	**18.** d	**19.** b	**20.** d
21. b	**22.** d	**23.** d	**24.** c	**25.** a
26. c	**27.** a	**28.** c	**29.** b	**30.** d
31. c	**32.** a	**33.** a	**34.** d	**35.** b
36. c	**37.** a	**38.** d	**39.** a	**40.** b
41. c	**42.** a	**43.** c	**44.** b	**45.** c
46. b	**47.** d	**48.** c	**49.** d	**50.** c
51. d	**52.** b	**53.** d	**54.** c	**55.** b

56. a	**57.** a	**58.** a	**59.** d	**60.** a
61. a, d	**62.** a, b, d	**63.** a, b, c	**64.** a, d	**65.** a, b

• General Hints •

Read the following rules of nomenclature in order to answer questions 4, 5, 10, 11, 12, 13, 15, 16, 25, 27, 28, 33, 34, 35, 36, 37, 38, 39, 40, and 63.

1. The symbol of the central atom is placed first in the formula of coordination compounds followed by those of anionic ligands in alphabetical order and then those of neutral ligands, again in alphabetical order.

2. Abbreviations of complicated organic formulae may be used in formulae.

3. The formula for a complex molecule or ion is enclosed in square brackets.

4. In names, that of the central atom is placed after the names of the ligands.

5. The neutral ligand H_2O is called *aquo*, and the neutral ligand NH_3 *ammine*.

6. For names, ligands are listed in alphabetical order regardless of the charge on the ligand or the number of ligands.

7. The names of anionic ligands end in 'O' (-ido, -ito, and ato commonly). The number of ligands of each kind is indicated by the prefixes di-, tri-, tetra-, penta-, hexa-, and so on, unless the prefix could be misinterpreted as a part of the name of the ligand. In such cases the prefixes bis, tris, tetrakis and so on, are used. For example, diammine for $2NH_3$ but bis (methylamine) for $2CH_3NH_2$, since dimethylamine is $(CH_3)_2NH$. The following are the exceptions for the names of anionic ligands (omit -id of -ido).

F^-—fluoro Cl^-—chloro Br^-—bromo I^-—iodo O^{2-}—oxo

OH^-—hydroxo O_2^{2-}—peroxo S^{2-}—thio CN^-—cyano.

8. The oxidation number of the central atom is indicated by the corresponding Roman numeral in parenthesis after its name.

9. Formulae and names may be supplemented by the italicized prefixes *cis*, *trans*, *fac* (facial), *mer* (meridianal) and so on.

10. Names of metal complex anions end in -ate. Complex cations and neutral molecules, e.g., NO and CO, do not have a distinguishing suffix.

11. A ligand, e.g., SCN^-, may be attached to the rest of the molecule through different atoms in different cases. These molecules may be distinguished as follows.

M–SCN stands for thiocyanato–S and M–NCS stands for thiocyanato–N

12. Bridging groups are indicated by prefixing the Greek letter μ to the names of the groups. Two or more bridging groups of the same kind are indicated by di-μ, and so on. If a bridging group bridges more than two metals, use μ_3, μ_4, etc.

• *Effective Atomic Number Rule (For questions 6, 7, 8 and 9)* •

The Effective Atomic Number (EAN) provides a rough guide for bonding in coordination compounds. Quite a few, but not all, metals achieve the EAN of a noble gas through coordination. The EAN of a metal ion is calculated by adding the electrons of the metal ion to those shared with it through coordination. In $[Co(NH_3)_6]^{3+}$, the cobalt (III) ion has 24 electrons plus 6 electron pairs from NH_3 molecules, making up a total of 36 electrons—the configuration of krypton.

EAN of cobalt ion in $[Co(NH_3)_6]^{3+} = (27 - 3) + 6 \times 2 = 36$ = atomic number of Kr

• *Coordination Compounds* •

Coordination compounds are formed when the available empty bonding orbitals of a metal are used for the formalion of coordinate bonds. The coordination number (CN) and geometry are determined in part by size and charge effects, but also to a great extent by the orbitals available for bonding. The common hybridized orbitals encountered in coordination compounds are given in Table 1.

See Tables 1 and 2 for answering Questions 18, 23, 41, 42, 48, 49 and 50.

Table 1 Hybrid orbitals for metal complex

Coordination no.	Hybridized orbital	Configuration	Examples
2	sp	Linear	$Ag(NH_3)_2^+$
3	sp^2	Trigonal planar	$Ag(PR_3)_3^+$
4	sp^3	Tetrahedral	$Ni(CO)_4$, $Zn(NH_4)_4^{2+}$
4	dsp^2	Planar	$Ni(CN)_4^{2-}$, $Pt(NH_3)_4^{2+}$
5	$d_{z^2}sp^3$ or d^3sp	Trigonal bipyramidal	$CuCl_5^{3-}$, $[Ni(PEt_3)_2Br_3]$
6	d^2sp^3	Octahedral	$Co(NH_3)_6^{3+}$, $PtCl_6^{2-}$

1. Those complexes in which there are no low-energy d-orbitals available for bond formation, e.g., $Ni(NH_3)_6]^{2+}$ or $[Fe(C_2O_4)_3]^{3-}$ (five unpaired electrons), are called "ionic" complexes.
2. Whether the electron populations of the d-orbitals are "low-spin" (or spin-paired) or high-spin (or spin-free) determine the magnetic properties of the molecule.
3. Covalent octahedral complexes and tetrahedral complexes are formed when d^2sp^3 and sp^3 orbitals respectively come into play. (See Table 2.)

Table 2 Electronic configurations of some metal complexes according to the valence bond (VB) theory

Ion or Complex	Configuration (3d 4s 4p)		High- or low-spin
Cr^{3+}	↑ ↑ ↑ – – – – – –		High-spin, paramagnetic
$Cr(NH_3)_6^{3+}$	↑ ↑ ↑ $\boxed{\uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow}$	Covalent (VB)	
Co^{3+}, Fe^{2+}	↑↓ ↑ ↑ ↑ ↑ – – – –		
$Co(NH_3)_6^{3+}$, $Fe(CN)_6^{4-}$	↑↓ ↑↓ ↑↓ $\boxed{\uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow}$	Covalent (VB)	Low-spin, diamagnetic
Co^{2+}	↑↓ ↑↓ ↑ ↑ ↑ – – – –	Ionic (VB)	
$Co(NH_3)_6^{2+}$	↑↓ ↑↓ ↑ ↑ ↑ – – – –		High-spin, paramagnetic
Zn^{2+}	↑↓ ↑↓ ↑↓ ↑↓ ↑↓ – – – –		
$ZnCl_4^{2-}$	↑↓ ↑↓ ↑↓ ↑↓ ↑↓ $\boxed{\uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow\ \uparrow\downarrow}$	Ionic (VB)	
$Zn(NH_3)_6^{2+}$	↑↓ ↑↓ ↑↓ ↑↓ ↑↓ – – – –		
Fe^{3+}	↑ ↑ ↑ ↑ ↑ – – – –		
$Fe(C_2O_4)_3^{3-}$	↑ ↑ ↑ ↑ ↑	Ionic (VB)	High-spin, paramagnetic
$Ni(NH_3)_6^{2+}$	↑↓ ↑↓ ↑↓ ↑ ↑		

• *Hints to Specific Problems* •

2. A hexadentate ligand will contain six donor atoms.

3. Dimethyl glyoxime contains two donor atoms.

6. In $Cu(CN)_4^{3-}$, Cu has an oxidation number of 1. Z = 29 for Cu. CN^- has one electron pair. Hence EAN = (29 – 1) + 4 × 2 = 36 (Kr)

7. In $[Pd(NH_3)_6]^{4+}$ (Z = 46 for Pd), oxidation number of Pd = +4.
EAN = (46 – 4) + 6 × 2 = 54

8. In $[Mn(H_2O)_6]^{2+}$ (Z = 25 for Mn), oxidation number of Mn = +2.
∴ EAN = (25 – 2) + 6 × 2 = 35
This value does not correspond to the atomic number of any noble gas.
So the EAN rule is violated.

18. In $Fe(CN)_6^{3-}$, the oxidation number of Fe = +3 and so it has a $3d^5$ configuration.
In $Fe(CN)_6^{4-}$, the oxidation number of Fe = +2 and so it has a $3d^6$ configuration.
In $Co(No_2)_6^{3-}$ the oxidation number of Co = +3 and so it has a $3d^6$ configuration.

	3d					4s	3p			
Fe (III)	↑	↑	↑	↑	↑					
$Fe(CN)_6^{3-}$	↑↓	↑↓	↑	X	X	X	X	X	X	d^2sp^3
Fe(II) and Co(III)	↑↓	↑	↑	↑	↑					
$Fe(CN)_6^{4-}$ and $Co(NO_2)_6^{3-}$	↑↓	↑↓	↑↓	X	X	X	X	X	X	d^2sp^3

19. The CN^- ion is a strong ligand.

21. There is no charge-transfer transition in Ti^{4+}.

23. In $[Mn(CN)_6]^{4-}$, Mn is in the +2 oxidation state.

The configuration of Mn^{+2} is $3d^5$ or

3d				
↑	↑	↑	↑	↑

The configuration of $[Mn(CN)_6]^{4-}$ is

3d				
↑↓	↑↓	↑		

n = 1 (no. of unpaired electron)

The unpaired electrons in the d orbitals pair up because CN^- has a strong ligand character.

$\mu_{spin} = \sqrt{n(n+2)}$ BM $= \sqrt{(1+2)} = \sqrt{3}$ BM $= 1.73$ BM

29. The configuration of Fe^{2+} is $3d^6$. It contains four unpaired electrons more than any of the other metal ions shown.

30. Co exists as Co^{3+} in $[Co(NH_3)_6]^{3+}$. The configuration of Co^{3+} is $3d^6$

or 3d

↑↓	↑	↑	↑	↑

.

The configuration of $[Co(NH_3)_6]^{3+}$ is 3d

↑↓	↑↓	↑↓		

.

This complex is spin-paired.

The unpaired electrons in the d orbitals pair up because NH_3 has a strong ligand character.

31. Co exists as Co^{3+} in $[CoF_6]^{3-}$. The configuration of Co^{3+} is $3d^6$ or

3d

↑↓	↑	↑	↑	↑

.

The configuration of CoF_6^{3-} is 3d

↑↓	↑	↑	↑	↑

.

The unpaired electrons in the d orbitals do not tend to pair up because F^- is weak ligand. (Ligands which cause a small degree of crystal-field splitting are said to be weak.)

Hence, this complex is spin-free.

44. Exchange of Co and Cr in the coordination sphere

47. Co is linked with —N and with —O respectively in the two compounds shown.

❑

17

Analytical Chemistry

• *Type 1* •

Choose the correct option. Only one option is correct.

1. Which among the following nitrite salts is sparingly soluble in water?

(a) KNO_2 (b) $AgNO_2$

(c) $Ba(NO_2)_2$ (d) NH_4NO_2

2. On heating, a white amorphous inorganic compound becomes yellow and, on cooling, turns white again. The salt may be

(a) $PbCO_3$ (b) $MgCO_3$

(c) $ZnCO_3$ (d) K_2CO_3

3. Which of the following does not sublime on heating?

(a) NH_4Cl (b) As_2O_3

(c) $HgCl_2$ (d) Sb_2S_3

4. Which of the following does not respond to the chromyl chloride test?

(a) $HgCl_2$ (b) KCl

(c) $CaCl_2$ (d) NaCl

5. On being heated with concentrated H_2SO_4, a mixture of solid NaCl and $K_2Cr_2O_7$ produces a gas. The gas is

(a) SO_2 (b) CrO_2Cl_2

(c) HCl (d) SO_3

6. Which of the following halides is almost insoluble in concentrated ammonia?

(a) AgI (b) AgF

(c) AgBr (d) AgCl

7. Bromide and iodide ions can be detected in a mixture of NaCl, NaBr and NaI by shaking an aqueous solution of the mixture with a particular reagent in the presence of a CCl_4 solvent. The reagent is

(a) an $AgNO_3$ solution (b) an $FeSO_4$ solution

(c) a $Ba(OH)_2$ solution (d) chlorine water

8. The hottest part of the flame of a Bunsen burner is the

(a) blue zone

(b) zone of complete combustion

(c) zone of partial combustion

(d) All parts of the flame are equally hot.

9. A salt heated with dilute H_2SO_4 and subsequently treated with a few drops of dilute $KMnO_4$ solution loses colour. The salt may be a

(a) sulphite (b) carbonate

(c) bicarbonate (d) nitrate

10. On treatment with HCl, an inorganic salt solution produces a white precipitate. The salt may contain

(a) Hg_2^{2+} (b) Hg^{2+}

(c) Zn^{2+} (d) Cd^{2+}

11. In a charcoal cavity test, a colourless salt, on fusion with cobalt nitrate, gives a green precipitate. The salt contains

(a) Al^{3+} (b) Cu^{2+}

(b) Ba^{2+} (d) Zn^{2+}

12. In the titration of oxalic acid against a $KMnO_4$ solution, the indicator used is

(a) methyl orange (b) potassium ferrocyanide

(c) KI/starch (d) no indicator is used

13. On being subjected to the borax-bead test, a salt produces a pink bead. The salt is

(a) an iron salt (b) a copper salt

(c) a nickel salt (d) a manganese salt

14. When the solution of an inorganic salt in sodium hydroxide is boiled, a pungent gas is produced which turns moist red litmus paper blue and a mercurous nitrate solution black. This experiment indicates that the salt contains

(a) CO_3^{2-} (b) NH_4^+

(c) Sn^{4+} (d) NO_2^-

15. Which of the following reagents may be used to identify Sr^{2+} ions in the presence of Ca^{2+} ions in a solution?

(a) NH_4Cl (b) $(NH_4)_2S_2O_8$

(c) $(NH_4)_2SO_4$ (d) $(NH_4)_2CO_3$

16. Which of the following reagents may be used to identify Ca^{2+} ions in the presence of Ba^{2+} ions in a hot dilute acetic acid medium?

(a) $(NH_4)_2CO_3$ (b) NH_4Cl

(c) $AgNO_3$ (d) $(NH_4)_2C_2O_4$

17. Which of the following metal ions (as its volatile chloride) turns the oxidizing flame of a Bunsen burner yellow-green?

(a) Cr^{3+} (b) Zn^{2+}

(c) Fe^{3+} (d) Ba^{2+}

18. If an inorganic salt turns a borax bead blue in an oxidizing flame as well as in a reducing flame, then the metal present in the salt is

(a) Co (b) Fe

(c) Cr (d) Ni

19. The constituents of which of the following pairs of ions in a dilute HCl medium cannot be separated by passing H_2S gas through it?

(a) Ca^{2+} and Hg_2^{2+} (b) Cu^{2+} and Cd^{2+}

(c) Zn^{2+} and Sn^{4+} (d) Co^{3+} and Cu^{2+}

20. The sulphides of which of the following groups of elements are soluble in yellow ammonium sulphide?

(a) As, Sb and Sn (b) As, Cd and Sn

(c) Cd, Cu and Bi (d) Hg, Cu and Cd

21. NaCl and Na_2SO_4 can be distinguished by

(a) Gutzeit's test (b) Marsh's test

(c) the flame test (d) the chromyl chloride test

22. On being heated with SiO_2 and concentrated H_2SO_4, a salt produces white fumes which give a white deposit on coming in contact with a moistened glass rod. The salt may be

(a) $CaSO_4$ (b) NaCl

(c) CaF_2 (d) KBr

23. An organic compound containing sulphur is oxidized by fuming HNO_3. By this treatment, S is converted to

(a) SO_2 (b) SO_3

(c) H_2S (d) H_2SO_4

24. In salt analysis, the interference due to PO_4^{3-} is removed
(a) after testing for Group 1
(b) after testing for Group 2
(c) after testing for Group 2 but before doing so for Group 3
(d) before proceding with the basic radicals

25. The green colour formed by adding KOH to $KMnO_4$ is due to the formation of
(a) MnO_4^{2-}
(b) Mn^{2+}
(c) Mn_2O_7
(d) MnO_2

26. Na_2SO_3 and Na_2S can be distinguished from each other by using
(a) concentrated H_2SO_4
(b) an acidified $KMnO_4$ solution
(c) an acidified $K_2Cr_2O_7$ solution
(d) a sodium nitroprusside solution

27. A salt mixture is heated with dilute HCl and the gaseous product is passed successively through an acidified $K_2Cr_2O_7$ solution and lime-water. The colour of the $K_2Cr_2O_7$ solution changes from orange to green, and the lime water becomes turbid. The salt mixture contains
(a) CO_3^{2-}
(b) SO_3^{2-}
(c) S^{2-}
(d) CO_3^{2-} as well as SO_3^{2-}

28. The addition of solid NH_4Cl to an aqueous solution of ammonia
(a) reduces the concentration of the hydroxide ions due to the common-ion effect
(b) increases the concentration of the hydroxide ions due to the common-ion effect
(c) increases the dissociation of ammonia due to the formation of Cl—OH
(d) does not change the concentration of the hydroxide ions

29. As_2S_3 dissolves in yellow ammonium sulphide to form
(a) $(NH_4)_3AsS_3$
(b) $(NH_4)_3AsS_4$
(c) $(NH_4)_2AsS_4$
(d) $(NH_4)_4AsS_3$

30. On treatment with KI, mercuric chloride gives a product X which is soluble in an excess of KI to form another product Y. X and Y are, respectively,
(a) HgI_2 and HgI_3^-
(b) HgI_2 and K_2HgO_3
(c) HgI_2 and K_2HgI_4
(d) Hg_2I_2 and K_2HgI_4

31. The yellow precipitate formed by passing ammonia gas into Nessler's reagent is due to the formation of

(a) HgI_4^{2-} (b) $NH_2O—Hg—HgI$
(c) $NH_2—Hg—O—Hg—I$ (d) $NH_2—Hg—I$

32. The purple colour obtained by adding a sodium nitroprusside solution to a sodium sulphide solution is due to the formation of

(a) $Na_2[Fe(CN)_6S]$ (b) $Na_4[Fe(CN)_5NOS]$
(c) $Na_2[Fe(CN)_6NOS]$ (d) $KFe[Fe(CN)_6NOS]$

33. An excess of an NaOH solution is added gradually to an aqueous solution of $ZnSO_4$. Which of the following happens?

(a) A white precipitate is formed which does not dissolve in the excess of NaOH.
(b) A green precipitate is formed which dissolves on the addition of the excess of NaOH.
(c) A white precipitate is formed which dissolves in the excess of NaOH.
(d) No observable change takes place.

34. In a group-separation operation, before precipitating out Group 3 metal ions as hydroxides, it is necessary to boil the solution of the salt mixture with a few millilitres of concentrated HNO_3. This is done to convert

(a) Co^{2+} to Co^{3+} (b) Fe^{2+} to Fe^{3+}
(c) Mn^{2+} to MnO_4^- (d) Cr^{3+} to CrO_4^{2-}

35. Which of the following pairs of compounds can exist together in solution?

(a) $FeSO_4$ and $Pb(NO_3)_2$ (b) Na_2CO_3 and NaOH
(c) $NaHCO_3$ and NaOH (d) $AgNO_3$ and NaCl

36. On treatment with dilute HCl, a white crystalline salt produces a yellow colloidal suspension with the evolution of a pungent gas. The gas turns limewater milky. The salt may be

(a) $NaHCO_3$ (b) Na_2SO_3 (c) $Na_2S_2O_3$ (d) $Na_2S_2O_7$

37. During a charcoal block reducing test, a grey residue is obtained which can make marks on paper. This test is performed to detect the presence of

(a) Fe^{2+} (b) Pb^{2+} (c) Hg^{2+} (d) Cd^{2+}

38. In a charcoal cavity test in an oxidizing flame (using cobalt nitrate), salts of aluminium, zinc and magnesium produce residues of specific colour. Which of the following gives the correct match of the composition and colour of the residue?

(a) $CoAl_2O_4 \longrightarrow$ Thenard's blue
(b) $CoZnO_2 \longrightarrow$ Rinmann's green
(c) $CoMgO_2 \longrightarrow$ Pale pink
(d) All of these

39. In a borax-bead test, a colourless bead becomes coloured on being heated with a colourless metal salt. This happens due to the formation of
(a) the borate and metaborate of the metal
(b) boric oxide
(c) the orthoborate of the metal
(d) the hexaborate of the metal

40. An insoluble salt (A) is readily soluble in concentrated ammonium acetate solution. The resulting solution on treatment with K_2CrO_4 gives a yellow precipitate which is insoluble in mineral acid. Identify A
(a) $PbSO_4$ (b) Ag_2SO_4
(c) $HgSO_4$ (d) $CaSO_4$

41. The presence of phosphate interferes with the detection of
(a) Pb^{2+} (b) Ca^{2+}
(c) Sn^{2+} (d) Bi^{3+}

42. A salt is heated with dilute H_2SO_4 and subsequently treated with a few drops of dilute $K_2Cr_2O_7$, upon which the entire solution turns green. The salt may be a
(a) chloride (b) nitrate
(c) sulphide (d) sulphate

43. Which of the following statement is incorrect for the borax-bead test of inorganic salts in an oxidizing flame?
(a) The formation of a green bead which turns blue upon cooling indicates the presence of Cu^{2+} in the salt.
(b) The formation of a blue bead which retains its colour on cooling indicates the presence of Co^{2+} in the salt.
(c) The formation of a dark yellow bead in the hot condition which becomes green upon cooling indicates the presence of Cr^{3+} in the salt.
(d) The formation of a green bead in hot as well as cold conditions indicates the presence of Mn^{2+} in the salt.

44. Which of the following pairs of compounds precipitates when their aqueous solutions are mixed together?
(a) $AlCl_3$ and $ZnSO_4$ (b) $FeSO_4$ and $BaCl_2$
(c) $Cu(NO_3)_2$ and NH_4Cl (d) NaF and $AgNO_3$

45. Which of the following is insoluble in dilute acids but soluble in alkalis?

(a) PbS (b) CdS
(c) FeS (d) Sb_2S_3

46. The constituents of which of the following pairs of ions can be separated using a concentrated NaOH solution?

(a) Al^{3+} and Sn^{2+} (b) Al^{3+} and Fe^{3+}
(c) Al^{3+} and Zn^{2+} (d) Zn^{2+} and Pb^{2+}

47. The brown ring test is performed for the detection of the

(a) nitrite ion (b) sulphite ion
(c) bromide ion (d) nitrate ion

48. Which of the following metal ions can be detected and estimated by using dimethyl glyoxime in an ammoniacal medium?

(a) Ni^{2+} (b) Co^{2+}
(c) Cd^{2+} (d) Mg^{2+}

49. Which of the following reagents can one use to distinguish between Na_2CO_3 and Na_2SO_3?

(a) Limewater (b) Baryta water
(c) Acidified $K_2Cr_2O_7$ solution (d) H_2SO_4 solution

50. Cu^{2+} and Cd^{2+} are detected in a mixture of their solutions by using

(a) KCN and H_2S
(b) HCl and H_2S
(c) $K_3[Fe(CN)_6]$ and H_2S
(d) concentrated NH_3 and H_2S

51. When a reagent A reacts with Fe^{3+} the solution turns red due to the formation of a compound B. The reagent causes no change in colour when it reacts with Fe^{2+} in the pure state. A and B are respectively

(a) $K_4[Fe(CN)_6]$ and $Fe_4[Fe(CN)_6]_3$
(b) NH_4CNS and $[Fe(SCN)]^{2+}$
(c) $K_3[Fe(CN)_6]$ and $K_2Fe[Fe(CN)_6]$
(d) Na_2HPO_4 and $FePO_4$

52. An aqueous solution of $FeSO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$ and chrome alum is heated with an excess of Na_2O_2 and filtered.

(a) A green filtrate and a brown residue
(b) A yellow filtrate and a green residue
(c) A yellow filtrate and a brown residue
(d) A colourless filtrate and a green residue

are obtained.

53. During the separation of Group IV metal ions as insoluble carbonates by the addition of a saturated solution of $(NH_4)_2CO_3$ to the salt sample in an ammoniacal medium containing an excess of NH_4Cl, magnesium is not precipitated either as $Mg(OH)_2$ or $MgCO_3$ because

(a) the concentrations of OH^- and CO_3^{2-} are so low due to the common-ion effect that the ionic product values of $Mg(OH)_2$ and $MgCO_3$ cannot exceed their respective solubility product values

(b) the solubility products of $Mg(OH)_2$ and $MgCO_3$ decrease due to the common-ion effect

(c) the solubility products of $Mg(OH)_2$ and $MgCO_3$ increase due to the common-ion effect

(d) all of these

54. Which of the following changes occur when a solution containing Mn^{2+} and Cr^{3+} is heated with an NaOH solution and H_2O_2?

(a) $Mn(OH)_2$ and $Cr(OH)_3$ precipitates which are formed initially dissolve due to the formation of Na_2MnO_4 and Na_2CrO_4.

(b) Soluble yellow Na_2CrO_4 and a brown precipitate of hydrated manganese dioxide are formed.

(c) A grey-blue gelatinous precipitate of $Cr(OH)_3$ and a white precipitate of $Mn(OH)_2$ are formed.

(d) Soluble Na_2MnO_4 and a grey-blue precipitate of $Cr(OH)_3$ are formed.

55. For the precipitation of Group IV metal ions as their insoluble carbonates, a saturated $(NH_4)_2CO_3$ solution is added to the salt sample in an ammoniacal medium, as a group reagent. But Na_2CO_3 or K_2CO_3 should not be used as the group reagent because

(a) they will prevent the precipitation of Group IV metal carbonates by forming soluble complex salts

(b) this would interfere with the Group V tests the presence or absence of Na^+ and K^+

(c) they will prevent the precipitation of Group IV metal ions by forming soluble metal hydroxides

(d) they will precipitate out Mg^{2+} ions of Group V (if present) along with Group IV metal carbonates

56. When a solution of a salt in dilute HNO_3 is treated with an ammonium molybdate solution, a yellow precipitate is obtained, indicating the presence of

(a) NO_2^- (b) SO_3^{2-}

(c) PO_4^{3-} (d) AsO_3^{3-}

• *Type 2* •

Choose the correct options. More than one option is correct.

57. On treatment with dilute H_2SO_4, an inorganic salt produces a gas which gives a milky precipitate when passed through limewater. The salt may be

(a) Na_2CO_3 (b) $NaNO_3$
(c) Na_2SO_3 (d) CH_3CO_2Na

58. Which of the following radicals in a 0.30 M HCl solution will be precipitated by passing H_2S through it?

(a) Cu^{2+} (b) Sb^{3+}
(c) Cd^{2+} (d) As^{3+}

59. When H_2S is passed through an ammoniacal solution of a salt, a precipitate is obtained. The salt may be a

(a) nickel salt (b) cobalt salt
(c) manganese salt (d) zinc salt

60. Which of the following cations can be detected by the flame test?

(a) K^+ (b) Ba^{2+}
(c) Sr^{2+} (d) Mg^{2+}

61. On being heated with concentrated HNO_3 and an ammonium molybdate solution, a salt solution gives a yellow precipitate. The salt may be

(a) Na_2HPO_4 (b) As_2O_3
(c) $FeSO_4$ (d) $BaCl_2$

62. The presence of which of the following radicals can be detected using dilute H_2SO_4?

(a) Chloride (b) Nitrate
(c) Sulphide (d) Sulphite

63. On treatment with H_2S gas, the solution of a salt in dilute HCl produces a black precipitate. The salt may be a

(a) copper salt (b) lead salt
(c) magnesium salt (d) nickel salt

64. In an ammoniacal solution, a salt produces a black precipitate when H_2S is passed through it. The salt may be a

(a) nickel salt (b) mercury salt
(c) cobalt salt (d) lead salt

65. Which of the following can be a primary standard?

(a) $Na_2S_2O_3 \cdot 5H_2O$ (b) $KBrO_3$

(c) $K_2Cr_2O_7$ (d) $Na_2B_4O_7 \cdot 10H_2O$

66. The sulphides of which of the following metals are soluble in a yellow ammonium sulphide solution?

(a) Sn (b) As

(c) Hg (d) Sb

67. On treatment with dilute H_2SO_4, a salt gives a gas which turns limewater milky. The salt may be

(a) $NaHCO_3$ (b) Na_2CO_3

(c) Na_2SO_3 (d) $NaNO_2$

68. K_2CrO_4 gives a yellow precipitate upon reacting with

(a) Ba^{2+} (b) Pb^{2+}

(c) Cu^{2+} (d) Fe^{3+}

69. The constituents of which of the following pairs of ions in a dilute HCl medium can be separated by passing H_2S through it?

(a) Cu^{2+}, Zn^{2+} (b) Cu^{2+}, Ni^{2+}

(c) Sn^{4+}, Bi^{3+} (d) Hg^{2+}, Fe^{3+}

70. An inorganic salt X is mixed with an equal quantity of MnO_2, and heated with concentrated H_2SO_4. A gas is evolved which reacts with potassium iodide, and one of the products will turn starch paper blue. X may be

(a) $NaHCO_3$ (b) NaCl

(c) $NaNO_3$ (d) KCl

Answers

1. b	**2.** c	**3.** d	**4.** a	**5.** b
6. a	**7.** d	**8.** b	**9.** a	**10.** a
11. d	**12.** d	**13.** d	**14.** b	**15.** c
16. d	**17.** d	**18.** a	**19.** b	**20.** a
21. d	**22.** c	**23.** d	**24.** c	**25.** a
26. d	**27.** d	**28.** a	**29.** b	**30.** c
31. c	**32.** b	**33.** c	**34.** b	**35.** b
36. c	**37.** b	**38.** d	**39.** a	**40.** a
41. b	**42.** c	**43.** d	**44.** b	**45.** d
46. b	**47.** d	**48.** a	**49.** c	**50.** a

51. b	**52.** c	**53.** a	**54.** b	**55.** b
56. c	**57.** a, c	**58.** a, b, c, d	**59.** a, b, c, d	**60.** a, b, c
61. a, b	**62.** c, d	**63.** a, b	**64.** a, c	**65.** b, c, d
66. a, b, d	**67.** a, b, c	**68.** a, b	**69.** a, b, d	**70.** b, d

Hints to More Difficult Problems

1. Polarization in the Ag^+ ion

2. Structural defect

4. $HgCl_2$ is a covalent compound. There is little interaction between the Hg and Cl atoms in the $HgCl_2$ molecule.

9. SO_2 reduces the violet $KMnO_4$ to the almost colourless Mn^{2+}.

12. $KMnO_4$ itself is coloured.

21. NaCl reacts positively to the chromyl chloride test whereas Na_2SO_4 does not.

26. Na_2S turns a dark purple-red upon reacting with $Na_2[Fe(CN)_5NO]$.

40. A green chromic salt is formed.

44. The insoluble $BaSO_4$ is formed.

49. On treatment with dilute HCl, Na_2CO_3 and Na_2SO_3 produce CO_2 and SO_2 respectively. SO_2 turns an acidified $K_2Cr_2O_7$ solution green whereas CO_2 does not change the colour of the solution.

57. CO_2 as well as SO_2 turn limewater milky.

58. Cu^{2+} and Cd^{2+} belong to Group IIA.
Sb^{3+} and As^{3+} belong to Group IIB.

67. CO_2 as well as SO_2 turn limewater milky.

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18

Assertion–Reason Questions

The questions consist of an *assertion* in column 1 and a *reason* in column 2. Use the following key to choose the appropriate answer.

(a) If the *assertion* as well as the *reason* are correct, and the *reason* is the correct explanation of the *assertion*.

(b) If the *assertion* as well as the *reason* are correct, but the *reason* is not the correct explanation of the *assertion*.

(c) If the *assertion* is correct but the *reason* is not.

(d) If the *reason* is correct but the *assertion* is not.

	Assertion	*Reason*
1.	FeI_3 cannot exist in an aqueous solution.	Fe^{3+} oxidizes I^- to I_2 easily.
2.	An aqueous solution of LiCl is slightly basic.	Li^+ polarizes H_2O molecules slightly.
3.	Graphite is chemically more reactive than diamond.	Diamond is very hard but graphite is soft.
4.	AlF_3 is almost insoluble in anhydrous HF but dissolves when NaF is added to it.	NaF produces free F^-.
5.	SF_6 exists but SH_6 does not.	$d\pi$-$p\pi$ bonding cannot take place in SH_6
6.	Many peroxides are coloured.	Diamagnetic superoxides are often found as impurities in these peroxides.
7.	The stability of peroxides and superoxides increases on passing from Li to Cs	The electropositive character of the elements in the periodic table increases on moving down a group.

	Assertion	Reason
8.	The reaction $O + 2e \rightarrow O^{2-}$ is endothermic and yet a large number of compounds containing the oxide ion do exist.	This reaction is exergonic.
9.	The compound $(CF_3)_3N$ shows almost no basic behaviour even though $(CH_3)_3N$ does.	There is no hydrogen bonding in $(CF_3)_3N$.
10.	The bond in ClF is 5% shorter and that in BrF 7% shorter than the sum of the respective single-bond radii.	The ionic character is greater in BrF.
11.	When CO_2 is passed through limewater, the solution turns milky but with an excess of CO_2, the solution becomes clear again.	Excess CO_2 changes the suspension to a colloidal solution
12.	When tritium is produced commercially, helium is also produced.	The nuclear reaction to produce tritium is $^{6}Li_3 + {}^{1}n_0 \rightarrow {}^{3}H_1 + {}^{4}He_2$
13.	NF_3 is not a Lewis base.	The dipole moment of NF_3 is not zero.
14.	SO_3 is a much stronger Lewis acid than CO_2.	The conjugate acid of SO_3 is much stronger than that of CO_2.
15.	$S_2O_8^{2-}$ is more oxidizing than SO_4^{2-}.	The oxidation number of sulphur in $S_2O_8^{2-}$ is more than that sulphur in SO_4^{2-}.
16.	HF has low volatility.	There is extensive hydrogen bonding in HF.
17.	$BaSO_4$ is less soluble than $CaSO_4$.	$BaSO_4$ is much heavier than $CaSO_4$.
18.	NH_3 has a higher boiling point than HF.	The N atom is attached to three H atoms, and the molecule exhibits hydrogen bonding.
19.	N_2H_4 cannot reduce $S_2O_3^{2-}$.	$S_2O_3^{2-}$ is converted to $S_4O_6^{2-}$.
20.	In liquid NH_3, Na and K are attracted towards the anode.	Na and K are converted to Na^- and K^-.
21.	Borazole is aromatic in nature.	Nitrogen contributes π-electrons to the system.
22.	The coordination number of N is seldom, if ever, 5 whereas that of P, which is in the same group, is 5 in a large number of compounds.	The first ionization energy of nitrogen is more than that of phosphorus.

23.	The azide ion is thermodynamically unstable but easily exists under normal conditions.	The azide ion is kinetically inert.
24.	Sodium is not produced commercially by the electrolysis of brine.	Sodium reacts violently with water.
25.	Fluorine cannot be produced electrolytically.	Water is oxidized at a much higher potential than fluorine, and any fluorine produced will rapidly react with water.
26.	$NaIO_3$ is converted to I_2 by using SO_2 rather than H_2O_2 or Sn^{2+}.	SO_2 is very cheap.
27.	Many metals produce coloured beads with borax.	Borax forms a glassy structure on heating, which optically influences light in a way that is characteristic of the metal involved.
28.	Mercuric salts produce a red precipitate with an iodide ion solution but the precipitate dissolves in an excess of the iodide.	In an excess of the iodide, colourless $[HgIO_3]^{2-}$ is formed.
29.	Orthophosphoric acid is added to the Zimmermann–Reinhardt reagent during the dichrometric titration of ferrous salts.	Orthophosphoric acid reduces the potential of the iron couple, thus aiding the oxidation of a ferrous salt.
30.	A permanganate is intensely coloured.	The major contribution to the colour is by the d-d transition in manganese.
31.	When a ferrous salt is added to a potassium hexacyano-ferrate (II) solution, a white precipitate is formed in the complete absence of air whereas a pale blue precipitate is formed under ordinary atmospheric conditions.	The white precipitate is due to the formation of $K_2Fe[Fe(CN)_6]$ and the pale blue precipitate due to the formation $Fe[Fe(CN)_6]$.
32.	The cyanide radical is a pseudohalogen.	The cyanide radical undergoes reactions similar to those of halogens
33.	All solids tend to have defects.	Defects cause nonstoichiometry in solids.

34.	The ionization energy of Cu is more than that of K though both have a $4s^1$ configuration.	The 18-electron shell of Cu shields nuclear charge more effectively than the shell of K.
35.	Ketene and diazomethane are structurally similar.	They are isoelectronic.
36.	The bond energy of NH_3 is less than that of PH_3.	Increasing size and decreasing electronegativity of the central atom permit the bonding electrons to be drawn out further, lowering the repulsion between the bonding pairs.
37.	Crystals of $NaHCO_3$ and $KHCO_3$ show hydrogen bonding of different kinds.	In $NaHCO_3$, the bicarbonate ions are linked in an infinite chain while in $KHCO_3$, a dimeric anion is formed.
38.	Graphite electrodes are not used in the electrolytic synthesis of fluorine.	Fluorine forms a highly explosive gunpowder-like mixture with graphite, which can explode even in darkness.

Answers

1. a	**2.** d	**3.** b	**4.** a	**5.** a
6. c	**7.** a	**8.** c	**9.** b	**10.** a
11. c	**12.** a	**13.** b	**14.** b	**15.** c
16. a	**17.** c	**18.** d	**19.** a	**20.** a
21. b	**22.** b	**23.** a	**24.** b	**25.** c
26. a	**27.** c	**28.** c	**29.** a	**30.** c
31. a	**32.** a	**33.** b	**34.** c	**35.** b
36. a	**37.** a	**38.** c		

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19

Matching-Type Questions (Chapterwise)

Periodic Table

1. 'Bismuth pentachloride' does not exist due to	(a) Promethium
2. $[Xe]4f^15d^16s^2$	(b) $PbI_4 \rightarrow PbI_2 + I_2$
3. $[Xe]4f^75d^16s^2$	(c) $2FeI_3 \rightarrow 2FeI_2 + I_2$
4. $[Kr]4d^{10}5s^2$	(d) Be and Al
5. Radius of La^{3+}	(e) Transition metal
6. Radioactive lanthanide element	(f) Inert-pair effect
7. Highest second ionization energy	(g) Cadmium
8. Disproportionation	(h) Cerium
9. Diagonal pairs	(i) Gadolinium
10. Ground-state electronic configuration is $(n-1)d^6ns^2$	(j) Close to the radius of the lutetium trivalent ion
	(k) Chromium
	(l) Manganese
	(m) Zinc
	(n) B and Si

Hydrogen and Oxygen

1. H_2 adsorber	(a) H_2O and NH_2^-
2. Repeated electrolysis of alkaline water	(b) Absorption of red light

3. Oxide that gives H_2O_2 on reacting with HCl	(c) A moderator as well as a coolant
4. Superoxide ions	(d) sp^2 Hybridization with σ bonding
5. Compound that is deuterated easily	(e) Tritium
6. Identical geometry	(f) $Na_2[Na_4(PO_3)_6]$
7. D_2O	(g) $Ca(OH)_2$
8. O_3 is slightly bluish	(h) Presence of superoxide ions
9. Water is softened by treating water with	(i) CH_3CH_2OH
10. The central elements in ozone and SO_2	(j) Stronger oxidizing agents than peroxide ions
11. $\Delta_{fus}H$ is maximum for	(k) BaO_2
12. Many peroxides are coloured	(l) D_2O
	(m) Pd
	(n) MnO_2
	(o) PbO_2
	(p) CH_3COCH_3
	(q) NH_3 and H_3O^+
	(r) In the presence of N_2
	(s) Absorption of violet light

Alkali Metals and Alkaline-Earth Metals—I

Conversion	Name of process
1. $NaCl \rightarrow NaOH$	(a) Down process
2. $NaCl \rightarrow Na_2CO_3$	(b) Spring reaction
3. $S \rightarrow Na_2S_2O_3$	(c) Polymerization
4. $NaPO_3 \rightarrow$ Graham's salt	(d) Solvay process
5. $NaCl \rightarrow Na$	(e) Castner–Kellner process

Alkali Metals and Alkaline-Earth Metals—II

1. An amphoteric hydroxide	(a) Mg(OH)Cl
2. The most basic hydroxide	(b) Mg and Cl_2
3. Setting of cement	(c) Chlorophyll
4. Electrolysis of carnallite produces	(d) Decrease in the hydration energy of the metal ions down the group
5. Estimation of Cl_2 available in bleaching power	(e) Decrease in the lattice energy of the compounds more rapidly than that in the hydration energy
6. Insoluble salt having an 8 : 4 coordination	(f) Hydration and gel formation
7. Biomolecule containing Mg	(g) $Ra(OH)_2$
8. $MgCl_2 \cdot 6H_2O$ on strong heating produces	(h) Iodometry
9. Decrease in the solubility of carbonates of group 2 elements down the group	(i) $Be(OH)_2$
10. Increase in the solubility of fluorides and hydroxides of group 2 elements down the group	(j) CaF_2
	(k) ATP
	(l) $Mg(OH)HCl \cdot 4H_2O$
	(m) Haemoglobin
	(n) Iodimetry
	(o) Mg, K, Cl_2

Boron

1. Boron is used in the preparation of	(a) Hydrolysis
2. Boron with NaOH produces	(b) The terminal B—H bond is a 2-centre 3-electron bond containing 12 valence electrons
3. Orthoboric acid	(c) Ammonolysis
4. Reaction of borax with water gives	(d) Glass
5. $B_2H_6 \rightarrow H_3BO_3$	(e) $B(OH)_3$ and $B(OH)_4^-$

6. $B_2H_6 \rightarrow$ borazine	(f) Hydrogen-bonded together to form 2D sheets with hexagonal symmetry
7. B_2H_6	(g) Na_3BO_3 and H_2
8. $B(OH)_3$	(h) Triangular BO_3^{3-} units
	(i) Polymer
	(j) $Na_2B_4O_7$ and H_2
	(k) Pyramidal BO_3^{3-} units
	(l) The terminal B—H bond is a 2-centre 3-electron bond containing 16 valence electrons
	(m) Hydrogen-bonded together to form 3D sheets with hexagonal symmetry

Carbon

1. C(graphite) $\rightarrow$ C(diamond)	(a) Calcium nitride
2. $Be_2C \rightarrow CH_4$	(b) Dehydration
3. Magnesium carbide $\rightarrow$ propene	(c) α-Sn
4. $K_4[Fe(CN)_6] \rightarrow CO$	(d) $p\pi$–$d\pi$ overlap between N and Si
5. Malonic acid $\rightarrow C_3O_2$	(e) No π bonding
6. $CO \rightarrow HCOONa$	(f) Hydrolysis
7. Heated CaC_2 and N_2 are required in the preparation of	(g) Addition of concentrated H_2SO_4
8. Diamond-type lattice	(h) High temperature and high pressure
9. $(SiH_3)_3N$ is planar	(i) Polymerization
10. $(CH_3)_3N$ is pyramidal	(j) Alkali fusion
	(k) Calcium cyanamide
	(l) Germanium
	(m) $p\pi$–$d\pi$ overlap between N—N and Si—Si
	(n) Neither σ nor π bonding

Silicon

1. A coordinately saturated compound/ion	(a) Si—O—Si linkages
2. A coordinately unsaturated compound/ion	(b) $Ca_3[Si_3O_9]$
3. No donor property	(c) Hydrolysis and condensation
4. $(SiH_3)_3N$	(d) SiF_6^{2-}
5. $(CH_3)_3N$	(e) CCl_4
6. Silicones	(f) Both sp^3 and sp^2 orbitals
7. $(CH_3)_3SiCl \rightarrow$ hexamethyldisiloxane	(g) $(SiH_3)_3N$
8. $SiCl_4 + CH_3MgCl$	(h) Decomposition
9. $SiF_4 + HF$	(i) sp^2 Orbitals only
10. A cyclic silicate	(j) Si—Si linkage
	(k) Si—C bond formation
	(l) SnF_5^-
	(m) $Be_3Al_2[Si_6O_{18}]$
	(n) sp^3 Orbitals only

Nitrogen

1. $HNO_3 \rightarrow N_2O_5$	(a) Hydrolysis
2. $N_2O_5 \rightarrow NO + NO_2 + O_2$	(b) Raschig process
3. $Zn + OH^- + NO_3^- \rightarrow NH_3$	(c) Oxidation by NaOCl
4. Detection of NO_3^- ions in the presence of NO_2^- ions	(d) High pressure
5. $NH_3 \rightarrow N_2H_4$	(e) Dehydration
6. $CaCN_2 \rightarrow$ urea	(f) Nitration followed by ring test
7. $NH_3 \rightarrow N_2$	(g) Decomposition
8. $NH_2OH \xrightarrow{H^+} N_2O + NH_4^+$	(h) Decomposition by urea
9. $NCl_3 \rightarrow NH_4OH + HOCl$	(i) Reduction

10. $NH_3 + CO_2 \rightarrow$ urea

(j) Decomposition by urea followed by ring test

(k) Disproportionation

(l) Addition reaction

Phosphorus

1. A reducing agent as well as a diprotic acid

2. A reducing agent as well as a monoprotic acid

3. A cyclic phosphate

4. $Mg(NH_4)PO_4 \rightarrow Mg_2P_2O_7$

5. $P_4 \rightarrow H_3PO_4$

6. $Ca_3(PO_4)_2 \cdot CaF_2 + H_2SO_4$

7. $Ca_3(PO_4)_2 \cdot CaF_2 + H_3PO_4$

8. PCl_5

(a) Superphosphate

(b) Triple superphosphate

(c) Ionic in the solid state

(d) H_3PO_3

(e) $H_6P_4O_{13}$

(f) $CuSO_4$

(g) H_3PO_2

(h) Ignition

(i) $AgNO_3$

(j) Covalent in the liquid state

Sulphur

1. $Fe_2(SO_4)_3 \cdot 9H_2O \rightarrow Fe_2O_3 + SO_3 + H_2O$

2. $C_6H_{12}O_6 \rightarrow C$

3. $SO_3 \rightarrow S_3O_9$

4. $H_2S_2O_8 \rightarrow H_2SO_4 + H_2SO_5$

5. $FeSO_4 \cdot 7H_2O \rightarrow Fe_2O_3 + SO_2 + SO_3$

6. $KMnO_4 + H_2SO_4 + H_2S \rightarrow K_2SO_4 + MnSO_4 + S + H_2O$

(a) Oxidation of the reducing agent

(b) Hydrolysis

(c) Mild heating

(d) Strong heating

(e) Dehydration

(f) Cyclization

The Halogens—I

1. $ClO^-(aq) \rightarrow ClO_3^-(aq) + Cl^-(aq)$	(a) N_3^-
2. $I_2 + KI$	(b) Used in photography
3. AgBr/hydroquinone	(c) $(CN)_2$
4. A pseudohalide ion	(d) BrF_3
5. Not an interpseudohalogen compound	(e) The product has a linear structure
6. A pseudohalogen	(f) Disproportionation
	(g) ICl_2^-

The Halogens—II

Compound	**Usage**
1. CCl_2F_2	(a) Insulating medium for high-voltage transformers
2. $(C_2F_4)_n$	(b) Insecticide
3. SF_6	(c) Anaesthetic
4. ClF_3	(d) Insulating material in cables
5. DDT	(e) Refrigerator

The Halogens—III

Molecule/ion	**Stucture**
1. ClF_3	(a) Linear
2. BrF_5	(b) Bent
3. IF_7	(c) Square pyramidal
4. ICl_2^-	(d) T-shaped
5. OF_2	(e) Pentagonal bipyramidal

The Noble Gases

1. Hydrolysis of XeF_4	(a) $XeF_4 + PtF_4$
2. Hydrolysis of XeF_6	(b) Clathrate

3. Host molecule + guest molecule	(c) Capped octahedral
4. $Xe + PtF_6$ + heat	(d) $XeO_3 + O_2 + HF$
5. Noble gases are difficult to liquefy	(e) $Xe[PtF_6]$
6. XeF_6	(f) Small dispersion forces
7. XeO_3F_2	(g) Positive Joule–Thomson coefficients above 40 K
	(h) Trigonal bipyramidal structure with a lone pair of electrons
	(i) XeO_3

Copper

1. $2Cu^{2+} + SO_3^{2-} + 2SCN^- + H_2O \rightarrow 2CuSCN + H_2SO_4$	(a) High enthalpy of sublimation and high ionization energy
2. $2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$ and $I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$	(b) d Electrons in copper are poorly shielded
3. High melting point of copper	(c) It absorbs approximately at 550 nm in the yellow region
4. The first IP of Cu is higher than that of K	(d) Cu in the +II oxidation state has an unpaired electron
5. Reactivity of Cu	(e) $Cu_2[Fe(CN)_6]$
6. $CuSO_4{\cdot}5H_2O$ is blue in colour	(f) Low enthalpy of sublimation and low ionization energy
7. Most of the copper(I) complexes are colourless	(g) Cu^+ ions have a d^{10} configuration
8. $CuSO_4 + Na_2S_2O_3$ (excess)	(h) d Electrons take part in metallic bonding
9. $CuSO_4$ + KCN (excess)	(i) Volumetric analysis of Cu
10. $CuSO_4 + K_4[Fe(CN)_6]$	(j) Gravimetric analysis of Cu
	(k) $Na_4[Cu_6(S_2O_3)_5]$
	(l) $K_3[Cu(CN)_4]$
	(m) $K_2[Cu(CN)_4]$
	(n) $Cu_3[Fe(CN)_5]$

Silver and Gold

1. AgBr is used in photography	(a) Refining of Ag
2. $Na_2S_2O_3$ is used in photography	(b) Lanthanide contraction
3. $AuCl_3$ on reacting with NH_3 forms	(c) Culminating gold
4. Cupellation process	(d) Pattinson process
5. Radius of Ag ≈ radius of Au	(e) Fulminating gold
6. Extraction of Ag involving KCN, O_2 and active metal	(f) As a light-sensitive material
	(g) As a fixer
	(h) As a developer
	(i) As a reducing agent
	(j) Gold sol
	(k) The ccp structures of both Ag and Au
	(l) McArthur–Forrest process
	(m) Parkes process

Iron

1. Rusting of iron	(a) SO_3 only
2. $FeSO_4 + (NH_4)_2SO_4 + H_2SO_4$	(b) Annealing
3. $FeCl_3 + K_4[Fe(CN)_6]$	(c) An electrochemical process
4. $FeCl_2 + K_3[Fe(CN)_6]$	(d) Quenching
5. $FeSO_4 + AuCl_3$	(e) Mohr salt
6. $Fe_2(SO_4)_3$ + heat	(f) Prussian blue
7. Steel is heated at high temperature and then cooled suddenly	(g) Colloidal gold
8. Steel is heated at high temperature and then cooled slowly	(h) Turnbull's blue
	(i) Fulminating gold
	(j) Ferric ammonium alum

	(k) An electrolytic process
	(l) A mixture of SO_2 and SO_3

Coordination Chemistry

1. $Ni(CO)_4$	(a) $[V(H_2O)_6]^{3+}$
2. $Ni(PPh_3)_2Cl_2$	(b) 34
3. $[Ni(NH_3)_4]^{2+}$	(c) Ziese's salt
4. $[Zn(NH_3)_4]^{2+}$	(d) $[Co(NH_3)_4H_2O]Cl$
5. Geometrical isomerism	(e) 54
6. $K^+[Pt(C_2H_4)Cl_3]^- \cdot H_2O$	(f) $[Co(NH_3)_6]^{3+}$
7. *cis–trans* Isomerism	(g) $[Mn(CN)_6]^{4-}$
8. EAN for $[Ni(CN)_4^{2-}]$	(h) Optical as well as *cis–trans* isomerism
9. EAN for $[Pd(NH_3)_6]^{4+}$	(i) Ma_4b_2
10. A low-spin (spin-paired) complex	(j) A diamagnetic species
11. A high-spin (spin-free) complex	(k) Square planar
12. A complex ion having a magnetic moment of 1.73 Bohr magnetons	(l) CoF_6^{3-}
13. A complex ion having a magnetic moment of 2.83 Bohr magnetons	(m) Tetrahedral
14. $[Ag(NH_3)_2]Cl$	(n) A paramagnetic species
	(o) 36
	(f) 56

Analytical Chemistry—I

1. Gas that turns moist lead acetate paper black	(a) Ni^{2+}
2. Salt + conc. H_2SO_4 + $K_2Cr_2O_7$	(b) Devarda's alloy and NaOH
3. Salt + H_2SO_4 + Mohr salt	(c) HCl and $BaCl_2$
4. Salt + Pb_3O_4 + conc. HNO_3	(d) Sodium nitroprusside
5. Salt + DMG + NH_3	(e) Hydrogen sulphide

6. NO_3^- and Br^- can be distinguished from each other by	(f) Chromyl chloride test
7. Na_2SO_3 and Na_2SO_4 can be distinguished from each other by	(g) Chloride
8. Na_2SO_3 and Na_2S can be distinguished from each other by	(h) Decomposition by urea followed by ring test
9. NaCl and Na_2SO_4 can be distinguished from each other by	(i) Nitrate
10. $NaNO_2$ and $NaNO_3$ can be distinguished from each other by	(j) Mn^{2+}
	(k) Co^{2+}
	(l) Zn, Co, Ni
	(m) Mg, Sn, Al

Analytical Chemistry—II

Flame coloration	Metal
1. Golden yellow	(a) Potassium
2. Lilac	(b) Strontium
3. Brick red	(c) Sodium
4. Crimson	(d) Barium
5. Yellowish green	(e) Calcium

Analytical Chemistry—III

Colour of borax bead in the oxidizing flame		Metal
Hot	*Cold*	
1. Green	Blue	(a) Manganese
2. Yellowish brown	Yellow	(b) Chromium
3. Yellow	Green	(c) Cobalt
4. Violet	Amethyst	(d) Iron
5. Blue	Blue	(e) Nickel
6. Violet	Reddish brown	(f) Copper

Aluminium

1. By-product of the Serpek process	(a) Sodium aluminium silicate and sodium pyrosulphide
2. Alums help in purifying water	(b) Sodium aluminium silicate
3. Anodized Al	(c) Amalgamation
4. Lapis lazuli, a blue rock	(d) Al electrically coated with Al_2O_3
5. Removing the self-protective oxide film from Al	(e) Coagulation of mud
6. Ultramarine	(f) NH_3
	(g) CO_2
	(h) Flocculation of mud
	(i) Zinc cobaltate
	(j) Aluminium electrically coated with lead(IV) oxide

Tin and Lead

Reaction	**Product**
1. $Pb \rightarrow Pb(CH_3COO)_2 \cdot 3H_2O$	(a) White lead
2. $PbCl_2 \rightarrow PbCrO_4$	(b) Common solder
3. $Pb(NO_3)_2 \rightarrow PbCrO_4 \cdot PbO$	(c) Minium
4. $Pb(CH_3COO)_2 \rightarrow 2PbCO_3 \cdot Pb(OH)_2$	(d) Black oxide of lead
5. $Pb_3O_4 \rightarrow PbO$	(e) Cassiterite
6. $PbO \rightarrow Pb_3O_4$	(f) Inorganic sugar
7. $SnCl_2 \rightarrow SnO_2$	(g) Chrome yellow
8. $Pb(NO_3)_2 \rightarrow PbO + Pb$	(h) Chrome red
9. $SnCl_4 + HCl \rightarrow H_2[SnCl_6]$	(i) Litharge
10. $Sn + Pb \rightarrow$ alloy	(j) A coordinately unsaturated compound
	(k) Massicot
	(m) Red lead
	(o) A coordinately saturated compound

Zinc and Mercury

1. Galvanized iron pipe	(a) Gravimetric estimation
2. $Fe + Hg \rightarrow Fe_xHg_y$	(b) Formation of a pigment known as lithopone
3. $ZnSO_4 + CN^- \rightarrow Zn(CN)_4^{2-} + SO_4^{2-}$	(c) Amalgamation
4. Complex halides of Hg^{II}	(d) Iron pipe dipped in molten nickel
5. $Zn \rightarrow Zn_2P_2O_7$	(e) Complex ion having tetrahedral structure
6. $ZnSO_4 + BaS$	(f) Nessler's reagent used to detect NH_3
	(g) No amalgam formation
	(h) Iron pipe dipped in molten zinc

Transition Elements and Lanthanoids

1. A pair of metals having the same density	(a) Cerium(IV) solution
2. Wilkinson's catalyst	(b) Lu
3. Adam's catalyst	(c) +III
4. A Ziegler–Natta catalyst	(d) K_2MnO_4
5. Fenton's reagent	(e) Na_2CrO_4
6. Baeyer's reagent	(f) $4f^1$
7. $MnO_2 + KNO_2$	(g) Pt/PtO
8. $CrO_2Cl_2 + NaOH$	(h) $Rh(Cl)(PhP)_3$
9. $(NH_4)_2Cr_2O_7 + heat$	(i) $FeSO_4/H_2O_2$
10. $Na_2Cr_2O_7 + NaOH$	(j) $TiCl_4/(C_2H_5)_3Al$
11. Occurrence of Ce^{4+}	(k) $KMnO_4/OH^-$
12. The most common oxidation state of rare-earth elements	(l) Cr_2O_3
13. A radioactive rare-earth element	(m) Ni and Co
14. An oxidizing agent used both in volumetric analysis and in preparative chemistry	(n) Ag and Au
	(o) $Na_2Cr_2O_7$
	(p) $4f^0$
	(q) +IV
	(r) Pm

Answers

Periodic Table

1. ↔ f	**2.** ↔ h	**3.** ↔ i	**4.** ↔ g	**5.** ↔ j
6. ↔ a	**7.** ↔ k	**8.** ↔ b, c	**9.** ↔ d, n	**10.** ↔ f

Hydrogen and Oxygen

1. ↔ m	**2.** ↔ l	**3.** ↔ k	**4.** ↔ j	**5.** ↔ i
6. ↔ a, q	**7.** ↔ c	**8.** ↔ b	**9.** ↔ f	**10.** ↔ d
11. ↔ e	**12.** ↔ h			

Alkali Metals and Alkaline-Earth Metals—I

1. ↔ e	**2.** ↔ d	**3.** ↔ b	**4.** ↔ c	**5.** ↔ a

Alkali Metals and Alkaline-Earth Metals—II

1. ↔ i	**2.** ↔ g	**3.** ↔ f	**4.** ↔ b	**5.** ↔ h
6. ↔ j	**7.** ↔ c	**8.** ↔ a	**9.** ↔ d	**10.** ↔ e

Boron

1. ↔ d	**2.** ↔ g, j	**3.** ↔ h, k	**4.** ↔ e	**5.** ↔ a
6. ↔ c	**7.** ↔ b	**8.** ↔ f		

Carbon

1. ↔ h	**2.** ↔ f	**3.** ↔ f	**4.** ↔ g	**5.** ↔ b
6. ↔ j	**7.** ↔ k	**8.** ↔ c, l	**9.** ↔ d	**10.** ↔ e

Silicon

1. ↔ e	**2.** ↔ l	**3.** ↔ g	**4.** ↔ i	**5.** ↔ n
6. ↔ a	**7.** ↔ c	**8.** ↔ k	**9.** ↔ d	**10.** ↔ b, m

Nitrogen

1. ↔ e	**2.** ↔ g	**3.** ↔ i	**4.** ↔ j	**5.** ↔ b
6. ↔ a	**7.** ↔ c	**8.** ↔ k	**9.** ↔ a	**10.** ↔ d

Phosphorus

1. ↔ d	**2.** ↔ g	**3.** ↔ e	**4.** ↔ h	**5.** ↔ f, i
6. ↔ a	**7.** ↔ b	**8.** ↔ c, j		

Sulphur

1. ↔ d	**2.** ↔ e	**3.** ↔ f	**4.** ↔ b	**5.** ↔ d
6. ↔ a				

The Halogens—I

1. ↔ f **2.** ↔ e **3.** ↔ b **4.** ↔ a, g **5.** ↔ d
6. ↔ c

The Halogens—II

1. ↔ e **2.** ↔ d **3.** ↔ a **4.** ↔ c **5.** ↔ b

The Halogens—III

1. ↔ d **2.** ↔ c **3.** ↔ e **4.** ↔ a **5.** ↔ b

The Noble Gases

1. ↔ d **2.** ↔ i **3.** ↔ b **4.** ↔ e **5.** ↔ f, g
6. ↔ b **7.** ↔ h

Copper

1. ↔ j **2.** ↔ i **3.** ↔ h **4.** ↔ b **5.** ↔ a
6. ↔ c, d **7.** ↔ g **8.** ↔ k **9.** ↔ l **10.** ↔ e

Silver and Gold

1. ↔ f **2.** ↔ g **3.** ↔ e **4.** ↔ a **5.** ↔ b
6. ↔ l

Iron

1. ↔ c **2.** ↔ e **3.** ↔ f **4.** ↔ h **5.** ↔ g
6. ↔ a **7.** ↔ d **8.** ↔ b

Coordination Chemistry

1. ↔ m **2.** ↔ k **3.** ↔ n **4.** ↔ j **5.** ↔ i
6. ↔ c **7.** ↔ d **8.** ↔ b **9.** ↔ e **10.** ↔ f
11. ↔ l **12.** ↔ g **13.** ↔ a **14.** ↔ h

Analytical Chemistry—I

1. ↔ e **2.** ↔ g **3.** ↔ i **4.** ↔ j **5.** ↔ a
6. ↔ b **7.** ↔ c **8.** ↔ d **9.** ↔ f **10.** ↔ h

Analytical Chemistry—II

1. ↔ c **2.** ↔ a **3.** ↔ e **4.** ↔ b **5.** ↔ d

Analytical Chemistry—III

1. ↔ f **2.** ↔ d **3.** ↔ b **4.** ↔ a **5.** ↔ c
6. ↔ e

Aluminium

1. ↔ f **2.** ↔ e **3.** ↔ d **4.** ↔ b **5.** ↔ c
6. ↔ a

Tin and Lead

1. ↔ f **2.** ↔ g **3.** ↔ h **4.** ↔ a **5.** ↔ i, k
6. ↔ c, m **7.** ↔ e **8.** ↔ d **9.** ↔ o **10.** ↔ b

Zinc and Mercury

1. ↔ h **2.** ↔ c **3.** ↔ e **4.** ↔ f **5.** ↔ a
6. ↔ b

Transition Elements and Lanthanoids

1. ↔ m **2.** ↔ h **3.** ↔ g **4.** ↔ j **5.** ↔ i
6. ↔ k **7.** ↔ d **8.** ↔ e **9.** ↔ l **10.** ↔ e
11. ↔ p **12.** ↔ c **13.** ↔ r **14.** ↔ a

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20

Matrix-Matching-Type Questions (Mixed)

Matrix A

1. Industrial synthesis of methanol	(a) CO
2. Water gas shifting reaction at 500°C	(b) PbI_4
3. Ostwald process	(c) O_2
4. Contact process	(d) H_2

Matrix B

1. $KI + O_3 + H_2O$	(a) Acid–base and/or redox titration
2. $KH_3(C_2O_4)_2 \cdot 2H_2O$	(b) Phenolphthalein and methyl orange indicators
3. $Na_2CO_3 + HCl$	(c) Theory of adsorption indicator
4. $AgNO_3 + NaCl$	(d) K_2CrO_4 solution

Matrix C

Reaction	**Change in hybridization of central atom**
1. $CH_4 \rightarrow CO_2$	(a) $sp^3 \rightarrow dsp^2$
2. $PCl_5 \rightarrow H_3PO_4$	(b) $sp^3 \rightarrow sp$
3. $HNO_3 \rightarrow N_2O_5$	(c) $sp^3d \rightarrow sp^3$
4. $Ni(CO)_4 \rightarrow Ni(CN)^{2-}$	(d) $sp^3 \rightarrow sp, sp^2$

Matrix D

1. Self-reduction process	(a) Purification of titanium
2. Carbon monoxide process	(b) Copper
3. Decomposition of iodide	(c) Iron
4. Face-centred-cubic lattice	(d) Pyrometallurgy

Matrix E

1. H_2S	(a) Weak dipole–dipole forces
2. CH_3OH	(b) London dispersion forces
3. C_2H_6	(c) Hydrogen bonding
4. HNO_3	(d) Large dipole–dipole forces

Matrix F

1. ICl_4^-	(a) Tetrahedral
2. Al_2Cl_6	(b) Octahedral
3. $Fe(CN)_6^{4-}$	(c) Square planar
4. I_2Cl_6	(d) d^2sp^3 Hybridization

Matrix G

1. Two unpaired electrons	(a) $Ni(en)_3^{2+}$
2. No unpaired electron	(b) VF_6^{3-}
3. Magnetic moment = 2.83 Bohr magnetons	(c) $Ni(CN)_4^{2-}$
4. Square-planar geometry	(d) $Fe(CN)_6^{4-}$

Matrix H

1. Silicon	(a) Semiconductor
2. The charge on the anion is equal to the number of terminal oxygen atoms	(b) Zone refining

3. Three shared corners and ten unshared corners	(c) SiO_4^{4-}
4. A silicon atom at the centre of the tetrahedron and an oxygen atom at each corner	(d) $Si_4O_{13}^{10-}$

Matrix I

1. Orthophosphoric acid	(a) Brønsted–Lowry acid
2. $B(OH)_3$	(b) Nonreducing triprotic acid
3. BF_3	(c) Weak Lewis acid having a hexagonal structure
4. Borazole	(d) Dehydrated product forming Graham's salt

Matrix J

1. P_4 molecule	(a) One equilateral triangular face of a tetrahedral molecule showing 60° bond angles and a 90° angle between the p orbitals
2. Triphosphate ion	(b) Strain would not be reduced by using sp^3 hybrid orbitals
3. Heating a stoichiometric mixture of the powdered orthophosphate salts Na_2HPO_4 and NaH_2PO_4	(c) Eutrophication
4. $P_3O_{10}^{5-}$ contributes to excessive fertilization and rampant growth of algae	(d) Synthetic detergent

Answers

Matrix A

	a	b	c	d
1	●	○	○	●
2	●	○	○	○
3	○	●	●	●
4	○	●	●	○

Matrix B

	a	b	c	d
1	●	○	●	○
2	●	○	○	○
3	●	●	○	○
4	○	○	●	●

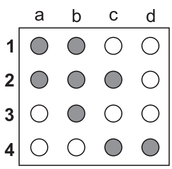
Matrix C

	a	b	c	d
1	○	●	○	○
2	○	○	●	○
3	○	○	○	●
4	●	○	○	○

Matrix D

	a	b	c	d
1	○	○	○	●
2	○	○	●	●
3	●	○	○	○
4	○	●	●	○

Matrix E



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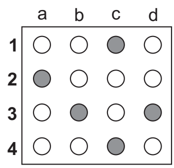

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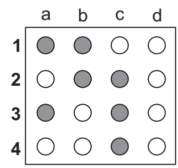

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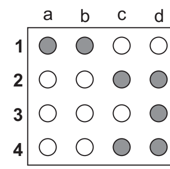
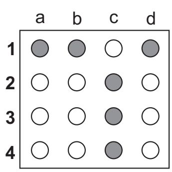


Matrix I



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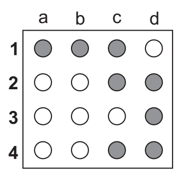

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21

Comprehension-Type Questions

- An aqueous solution of a boron compound (A) is alkaline in the presence of phenolphthalein, and the aqueous solution of (A) in phenolphthalein can be decolorized by the addition of glycerol. When the solid compound (A) is strongly heated, two solid substances (B) and (C) are produced. When the solid product mixture of (B) and (C) is boiled with water and filtered, the filtrate contains only (C). Addition of H_2O_2 to (C) produces a peroxo compound (D). (B) is heated with a mixture of carbon and chlorine to give a volatile substance (E). (E) on heating with NH_4Cl at 140°C gives (F). (F) on reaction with $NaBH_4$ in ether produces (G). (G) on hydrolysis yields a gaseous mixture (H).

Choose the correct option. Only one option is correct.

1. The compound (A) is

(a) B_2O_3 (b) $NaBO_2$

(c) $B(OH)_3$ (d) $Na_2B_4O_7 \cdot 10H_2O$

2. The compounds (B) and (C) are respectively

(a) $B(OH)_3$ and B_2O_3 (b) B_2O_3 and $NaBO_2$

(c) $NaBO_2$ and H_3BO_3 (d) B_2H_6 and B_2O_3

3. The compound (D) is used as

(a) a brightener in the preparation of washing powder

(b) an antiseptic in medicine

(c) an analgesic in medicine

(d) a water softener

4. The compound (E) has a

(a) tetrahedral structure

(b) plane triangular structure

(c) linear structure

(d) trigonal bipyramidal structure

5. The percentage of chlorine in the molecule of (F) is

(a) 27.63 (b) 17.63 (c) 19.75 (d) 15.43

6. The molecule of (G) is isoelectronic with

(a) benzene, and the bond order is greater than 1.0

(b) cyclohexane, and the bond order is less than 1.5

(c) diborane, and the bond order is equal to 2.0

(d) benzene, and the bond order equals 1.0

7. The gaseous mixture (H) contains

(a) NH_3 and N_2O (b) NH_3 and O_2

(c) NH_3 and H_2 (d) NH_3 and BF_3

- A black mineral (A) on heating in the presence of air gives a gas (B). The mineral (A) on reaction with dilute H_2SO_4 gives a gas (C) and the solution of a compound (D). On passing (C) into an aqueous solution of (B), white turbidity is obtained. The aqueous solution of (D) on reaction with $K_3[Fe(CN)_6]$ gives a blue compound (E).

8. The mineral (A) is

(a) ZnS (b) FeS (c) FeS_2 (d) Fe_2O_3

9. The gas (B) obtained is

(a) SO_2 (b) SO_3 (c) H_2S (d) O_2

10. The gas (C) is

(a) CO_2 (b) SO_2 (c) H_2S (d) N_2O

11. The aqueous solution of (D) contains

(a) $FeSO_4$ (b) $FeSO_4 \cdot (NH_4)_2SO_4$

(b) $FeCl_2$ (d) $FeCl_3$

12. The blue compound (E) must be

(a) $K_4Fe^{II}[Fe^{III}(CN)_6]$ (b) $K_2Fe^{II}[Fe^{II}(CN)_6]$

(c) $K_3Fe^{III}[Fe^{II}(CN)_6]$ (d) $KFe^{II}[Fe^{III}(CN)_6]$

- A green solid (A) on electrolytic oxidation in the alkaline medium gives a purple-coloured solution (B). The solution (B) oxidizes KI in the acidic medium and liberates (C), which reacts with chlorine water to give (D) and HCl. The potassium salt of (D) when heated gives O_2.

13. The green solid compound (A) showing sp^3 hybridization is

(a) K_2MnO_4 (b) $FeSO_4 \cdot 7H_2O$

(c) $NiSO_4 \cdot 6H_2O$ (d) $CuSO_4 \cdot 5H_2O$

14. The purple colour of the solution (B) is due to
(a) $Co(NO_3)_2$ (b) $MnCl_2$
(c) $KMnO_4$ (d) $K_3[Co(NO_2)_6]$

15. The compound (C) liberated is
(a) a mild reducing agent
(b) a strong reducing agent
(c) used in preparing tincture of iodine in the silk industry
(d) used to perform iodoform test

16. The compound (D) produced is
(a) $HClO_3$ (b) $HMnO_4$ (c) HIO_3 (d) KO_3

- A compound (A) is boiled with H_2SO_4 to give gypsum and an acid (B). (B) on gentle heating gives (C) and on strong heating gives (D).

17. The compound (A) is
(a) a gem (b) a mineral (c) a rock (d) none of these

18. The acid (B) is a
(a) monoprotic acid having sp^3 hybridization
(b) diprotic acid having sp^3d hybridization
(c) triprotic acid having sp^3 hybridization
(d) triprotic acid having dsp^2 hybridization

19. The compound (C) shows
(a) sp^3–sp^2 overlapping (b) sp–sp^3 overlapping
(c) sp^3–sp overlapping (d) sp^3–sp^3 overlapping

20. The compound (C) is
(a) pyrophosphoric acid (b) orthophosphoric acid
(c) hypophosphorous acid (d) pyrophosphorous acid

21. The sodium salt of (D) is known as
(a) Glauber's salt (b) Graham's salt
(c) Rochelle salt (d) Ziese's salt

- A white crystalline solid (A) decomposes on heating, leaving no residue. The gaseous substances evolved include water vapour and a gas (B), which rekindles a glowing splint. The solid (A) dissolves in water, yielding a colourless solution. The aqueous solution of (A) with a fresh $FeSO_4$ solution and concentrated H_2SO_4 produces a brown ring. The aqueous solution of (A) with alkali produces a gas (C), which responds positively to Nessler's reagent.

22. The white salt (A) shows
(a) sp^3–sp^2 overlapping (b) sp^3–sp overlapping
(c) sp^3–sp^3 overlapping (d) sp^3–dsp^2 overlapping

23. The gas (B) has a
(a) bent structure with a high dipole moment
(b) bent structure with a zero dipole moment
(c) linear structure with a very low dipole moment
(d) linear structure with a high dipole moment

24. The gas (B) is neutral, having the molecular formula
(a) CO_2 (b) NO_2 (c) CO (d) N_2O

25. The IUPAC name for the brown ring is
(a) pentaaquairon(III) sulphate
(b) pentaaquairon(I) nitrosyl sulphate
(c) pentaaquanitrosoiron(II) sulphate
(d) pentaaquanitrosyliron(I) sulphate

26. In the brown ring the oxidation number of Fe is
(a) +2 (b) +1 (c) 0 (d) +3

27. The brown colour in Nessler's reagent is due to the formation of
(a) $H_2NHgOHgNH_2I$ (b) $H_2NHg_2I_2$
(c) $NH_2Hg_2I_3$ (d) $NH_2OHg_2I_3$

- A colourless crystalline solid (A) turns skin black. It gives two gases—(B) and (C)—and a residue (D) when (A) is heated to 950°C. One of the gases is soluble in water yielding an acidic solution (E). The residue (D) is soluble in (E). The solid (A) gives a brown precipitate with NaOH solution. The brown precipitate produces an Ag mirror with glucose. The aqueous solution of (A) gives a white precipitate, which redissolves in excess KCN solution, forming a stable complex (F). Addition of Zn to (F) gives (D).

28. The white solid (A) is
(a) horn silver (b) argentite
(c) silver glance (d) lunar caustic

29. The gas (B) having a bent structure has a tendency to
(a) dimerize (b) dissociate (c) polymerize (d) trimerize

30. The solution (E) is acidic due to the presence of
(a) HNO_2 (b) HNO_4 (c) N_3H (d) HNO_3

31. The gas (B) has a bond angle approximately equal to
(a) 180° (b) 134° (c) 115° (d) 120°

32. The gas (C), which is paramagnetic and have a bond order equal to 2, is obtained by heating
(a) $KClO_3$ (b) HgO
(c) Pb_3O_4 (d) all of these

33. The brown precipitate is due to the formation of

(a) Ag(OH) (b) Ag_2O (c) $AgClO_4$ (d) $AgNO_2$

34. The structure of the complex (F) is

(a) sp^2 (b) sp (c) sp^3 (d) dsp^2

35. The addition of Zn to (F) is known as

(a) McArthur–Forrest cyanide process
(b) Pattinson process
(c) Raschig process
(d) none of these

- A white solid (A) is not completely soluble in dilute HCl/H_2SO_4 but dissolves readily in dilute HNO_3, evolving an acidic gas (B). The gas (B) continues to burn with magnesium. (A) on heating gives a yellow solid (C), which is an amphoteric oxide. (C) when heated in air forms a red compound (D), which dissolves in concentrated HNO_3, giving a brown residue (E).

36. The compound (A) is known as

(a) anglesite (b) cerrusite
(c) litharge (d) minium

37. The burning of Mg with (B) in the atmosphere produces

(a) MgO only (b) Mg_3N_2 only
(c) Mg (d) MgO and Mg_3N_2

38. The compound (A) is used to prepare

(a) white lead (b) alloys
(c) Zn by electrolysis (d) all of these

39. The yellow solid (C) is

(a) PbO_2 (b) Pb_3O_4
(c) PbO (d) $PbSO_4$

40. The red-coloured compound (D) is known as

(a) minium (b) litharge (c) fool's gold (d) vermilion

41. The compound (E) is used to prepare

(a) car batteries (b) alkaline batteries
(c) lithium cells (d) Weston cadmium cells

- A colourless compound (A) reacts with oxalic acid to give a paramagnetic molecule (B), a gas (C), and sodium oxalate. The compound (B) reacts with ozone to produce Cl_2O_6 and a gas (D).

42. The compound (A) imparts a flame coloration of

(a) violet (b) brick red
(c) crimson (d) golden yellow

43. The compound (A) on heating produces
(a) Cl_2 (b) O_2
(c) a metal oxide (d) ClO_2

44. The paramagnetic molecule (B) has
(a) no tendency to dimerize (b) a tendency to dimerize
(c) a bent structure (d) a linear structure

45. The gas (D) may be produced by
(a) the electrolysis of acidulated water
(b) the electrolysis of an aqueous Na_2SO_4 solution
(c) the electrolysis of an aqueous $KMnO_4$ solution
(d) all of these

- A colourless crystalline compound (A) loses the water of crystallization on heating. (A) reacts with dilute HCl, giving a pungent-smelling gas (B) and a yellow colloidal particle (C). The gas (B) turns an acidified dichromate solution into a green solution (D). (A) decolorizes an I_2 solution in KI to give (E). (A) gives a white precipitate (F) with $AgNO_3$ and turns black on standing.

46. The oxidation numbers of the central element in the compound (A) are
(a) +2, 0, –1 (b) +4, –2 (c) +4, +2 (d) +2, –2

47. The central element in the molecule of (A) has the hybridization
(a) sp^2 (b) sp (c) sp^3 (d) dsp^2

48. The gas (B) is
(a) $SO_3\left(sp^3, 109\frac{1^\circ}{2}\right)$ (b) $SO_2\,(sp^3, 120°)$
(c) $SO_3\,(sp^2, 120°)$ (d) $SO_2\,(sp^2, 120°)$

49. The yellow particle (C) is a
(a) solid dispersed in a liquid (b) solid dispersed in a solid
(c) gas dispersed in a solid (d) liquid dispersed in a liquid

50. The green solution (D) contains
(a) Cu^{2+} (b) Ni^{2+}
(c) Cr^{6+} (d) Cr^{3+}

51. I_2 dissolved in I^- giving I_3^- (3 lone pairs) have
(a) sp^3d hybridization with a bent structure
(b) sp^3d hybridization with a trigonal bipyramid structure
(c) sp^3d hybridization with a linear structure
(d) sp^3d hybridization with a T-shaped structure

52. The indicator used in iodometric titration is
(a) starch
(b) $CuSO_4$
(c) barium diphenylamine sulphonate
(d) alizarin yellow

53. The colourless substance (E) obtained is
(a) $Na_2S_2O_3$ (b) $Na_2S_4O_6$
(c) NaI (d) none of these

54. The white precipitate (F) and the black precipitate (G) are respectively
(a) AgCl and Ag_2S (b) Ag_2S and $Na_2S_4O_6$
(c) $Na_3[Ag(S_2O_3)_2]$ and Ag_2SO_4 (d) $Ag_2S_2O_3$ and Ag_2S

55. Which of the following complexes is produced by (A) with excess $AgNO_3$?
(a) $Na_3[Ag(S_2O_3)_2]$ (b) $Na_4[Ag_6(S_2O_3)_5]$
(c) $Na_2[Ag(S_2O_3)_2]$ (d) None of these

- A white crystalline solid (A) does not decompose on heating. When warmed with concentrated H_2SO_4, it gives a reddish brown gas (B), which when passed into water gives a colourless solution. The aqueous solution of (A) in dilute $HNO_3/AgNO_3$ produces a pale yellow precipitate (C), which dissolves in excess $Na_2S_2O_3$ to produce a soluble complex (D). The compound (A) in concentrated HCl imparts a lilac colour flame.

56. The compound (A) is a salt of
(a) lithium (b) manganese
(c) potassium (d) calcium

57. The gas (B) may be
(a) NO_2 only (b) $NO_2 + Br_2$
(c) $Br_2 + I_2$ (d) $NO + Br_2$

58. The gas (B) dissolved in excess chlorine water produces
(a) BrCl (b) HClO
(c) HBrO (d) $HBrO_3$

59. The product (C) on fusion with Na_2CO_3 gives
(a) Ag_2O (b) Ag
(c) Ag_2CO_3 (d) a mixture of Ag_2O and Ag

60. The brown gas (B) dissolves in Na_2CO_3 solution, producing two compounds containing elements with oxidation numbers –1 and +3 respectively. The mixture on boiling with concentrated H_2SO_4 produces

(a) (C) (b) (D) (c) (B) (d) none of these

61. The complex (D) so produced has

(a) an intense yellow colour (b) no colour
(c) a light pink colour (d) a deep blue colour

62. The compound (C) is mixed with quinhydrone used in

(a) photography (b) photosensitization
(c) tomography (d) metallurgy

Answers

1. d	**2.** b	**3.** a	**4.** b	**5.** b
6. a	**7.** c	**8.** b	**9.** a	**10.** c
11. a	**12.** d	**13.** a	**14.** c	**15.** d
16. c	**17.** b	**18.** c	**19.** d	**20.** a
21. b	**22.** a	**23.** c	**24.** d	**25.** d
26. b	**27.** c	**28.** d	**29.** a	**30.** d
31. b	**32.** d	**33.** b	**34.** b	**35.** a
36. b	**37.** d	**38.** a	**39.** c	**40.** a
41. a	**42.** d	**43.** b	**44.** c	**45.** d
46. b	**47.** c	**48.** d	**49.** a	**50.** d
51. c	**52.** a	**53.** b	**54.** d	**55.** a
56. c	**57.** b	**58.** d	**59.** b	**60.** c
61. b	**62.** a			

❑

Part 3

Organic Chemistry

1

Classification, Nomenclature and Hybridization

Choose the correct option. Only one option is correct.

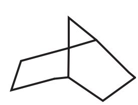
1. The name of

$$CH_3CH(C_6H_5)CH_2\underset{\underset{OH}{|}}{C}H-CH_2CH_3$$

is

(a) 1-ethyl-3-phenyl-1-butanol
(b) 2-phenyl-4-hexanol
(c) 5-phenyl-3-hexanol
(d) 5-benzyl-3-hexanol

2. The name of



is

(a) bicyclo [2.2.1] heptane
(b) methylene cyclohexane
(c) ethylene cyclopentane
(d) none of these

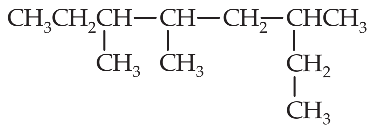
3. The IUPAC name of

$$CH_3CH_2-CH_2-\overset{\overset{CH_2=CH_2}{|}}{C}H-CH_2CH_2CH_3$$

is

(a) 3-propyl-1-hexene
(b) 3,3-dipropyl-1-propene
(c) 4-ethenyl-heptane
(d) none of these

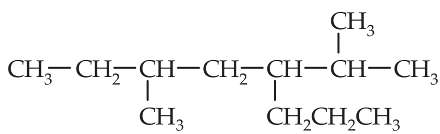
4. The IUPAC name of



is

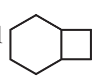
(a) 3, 4-dimethyl-6-ethylheptane
(b) 2-ethyl-4,5-dimethylheptane
(c) 3,4,6-trimethyloctane
(d) 3,5,6-trimethyloctane

5. The IUPAC name of



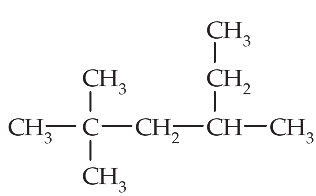
is

(a) 2,5-dimethyl-3-propylheptane
(b) 3,6-dimethyl-5-propylheptane
(c) 3-methyl-5-isopropyloctane
(d) none of these

6. The name of the compound  is

(a) bicyclo [2.2.2] octane
(b) bicyclo [3.2.1] octane
(c) bicyclo [4.1.1] octane
(d) bicyclo [4.2.0] octane

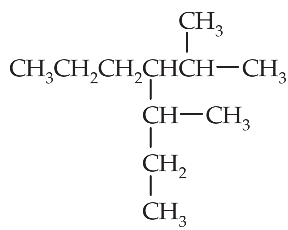
7. The IUPAC name of



is

(a) 2,2-dimethyl-4-ethylpentane
(b) 3,5,5-trimethylhexane
(c) 2,2,4-trimethylhexane
(d) 1-tert. butyl-2-ethylpropane

8. The IUPAC name of

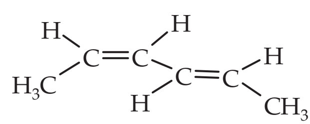


is

(a) 4-sec. butyl-5-methylhexane (b) 2-methyl-3-sec. butylhexane

(c) 2-methyl-3-isobutylhexane (d) 3-methyl-4-isopropylheptane

9. The correct name of the structure



is

(a) (E), (E)-2, 4-hexadiene (b) (Z), (Z)-2, 4-hexadiene

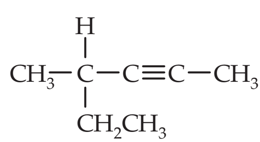
(c) (E), (Z)-3, 5-hexadiene (d) (Z), (E)-2, 4-hexadiene

10. Which of the following is a cumulated diene?

(a) 1,3-Pentadiene (b) 1,4-Pentadiene

(c) 2,3-Pentadiene (d) 1,5-Hexadiene

11. The IUPAC name of

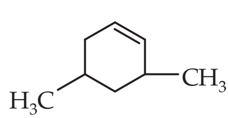


is

(a) 3-methyl-4-hexyne (b) 4-methyl-2-hexyne

(c) 4-ethyl-2-pentyne (d) 2-ethyl-3-pentyne

12. The IUPAC name of



is

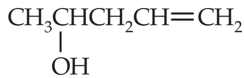
(a) 3,5-dimethylcyclohexene (b) 4,6-dimethylcyclohexene

(c) 3-methyltoluene-4-ene (d) none of these

13. The IUPAC name of $H{-}C{\equiv}C{-}CH_2CH{=}CH_2$ is

(a) 3-acetynyl-1-propene (b) 1-penten-4-yne
(c) acetylene-1-propene (d) none of these

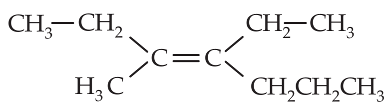
14. The IUPAC name of



is

(a) 4-hydroxypentene-1 (b) ethenylisopropanol
(c) 4-penten-2-ol (d) 2-hydroxy-4-pentene

15. The IUPAC name of



is

(a) 4-ethyl-3-methyl-*trans*-3-heptene
(b) 4-ethyl-3-methyl-*cis*-3-heptene
(c) 5-ethyl-6-methyl-*trans*-5-heptene
(d) 5-ethyl-6-methyl-*cis*-5-heptene

16. 1, 2-dimethylcyclopropane exhibits

(a) geometrical isomerism (b) position isomerism
(c) optical isomerism (d) nuclear isomerism

17. How many structural isomers can compounds with the molecular formula C_4H_8 have?

(a) One (b) Two
(c) Three (d) Four

18. How many structures can heptane (C_7H_{16}) have?

(a) Five (b) Six (c) Eight (d) Nine

19. Which of the following can have functional-group isomerism?

(a) $CH_3OC_2H_5$ (b) $CH_3CH_2NH_2$
(c) $CH_3CH_2CH{=}CH_2$ (d) none of these

20. How many stereoisomers of cyclopropane 1, 2-dicarboxylic acid are possible?

(a) One (b) Two (c) Three (d) Four

21. Which of the following statements is true about a homologous series?

(a) Adjacent members of a group differ by a mass of 14.
(b) Adjacent members of a group differ by one —CH_2 group.

(c) Members of a homologous series can be prepared by the same general methods.

(d) Members of a homologous series have the same physical and chemical properties.

22. The large number of organic compounds is due to

(a) the valency of carbon

(b) the small size of carbon

(c) a special property of carbon known as catenation

(d) none of these

23. How many isomers are possible for the alkyl group C_4H_9— ?

(a) Two (b) Three

(c) Four (d) Five

24. Which of the following compounds will have only primary and tertiary carbon?

(a) Pentane (b) 2-Methylbutane

(c) 2,3-Dimethylbutane (d) 2-Bromo-2-methylpropane

25. Which of the following compounds will have only primary and secondary carbon?

(a) Propane (b) 2,2,3-Trimethylpentane

(c) 2-Methylpropane (d) *n*-Propylbromide

26. Which of the following compounds has an isopropyl group?

(a) 2-Methylpentane (b) 2,2-Dimethylpentane

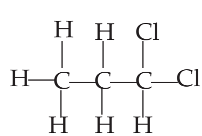
(c) 2,2,3,3-Tetramethylpentane (d) 2,2,3-Trimethylpentane

27. The general molecular formula of an alkyne is

(a) C_nH_{2n+2} (b) C_nH_{2n}

(c) C_nH_{2n-2} (d) $C_nH_{2n+1}OH$

28. The IUPAC name of



is

(a) 1,2-dichloropropane (b) 3,3-dichloropropane

(c) 1,1-dichloropropane (d) dichloropropane

29. The IUPAC name of $(CH_3)_2CHCH(CH_3)_2$ is

(a) 1,1,2,2-tetramethylethane (b) 1,2-di-isopropylethane

(c) 2,3-dimethylbutane (d) 2,3,3-trimethylbutane

30. The IUPAC name of $CH_3OCH_2CH_2CH_3$ is
(a) propoxymethane (b) methoxypropane
(c) methylpropyl ether (d) propylmethyl ether

31. The IUPAC name of $Cl—CH_2—\underset{\displaystyle Cl}{\underset{|}{C}}H—CH_2Cl$ is
(a) 1,2,3-trichloropropane
(b) 1,2-dichloropropyl chloride
(c) 1,1-dichloroisopropyl chloride
(d) propane trichloride

32. The IUPAC name of CH_3CHO is
(a) acetaldehyde (b) formyl methane
(c) ethanal (d) methylaldehyde

33. The IUPAC name for CH_3CH_2COOH is
(a) ethane carboxylic acid (b) ethanoic acid
(c) ethylformic acid (d) propanoic acid

34. The IUPAC name of $CH_3CH_2\underset{\displaystyle CH_3}{\underset{|}{C}}HCH_2CH_2CH_2CH_3$ is
(a) 5-methylheptane (b) 3-methylheptane
(c) 1-methyl-1-ethylpentane (d) 2-ethylhexane

35. The IUPAC name of $CH_3COCH_2CH_2CH_3$ is
(a) 2-pentanone (b) 4-pentanone
(c) methylpropylketone (d) ethylacetone

36. The IUPAC name of CCl_3CHO is
(a) 1,1,1-trichloroethanal (b) 2,2,2-trichloroethanal
(c) trichloroacetaldehyde (d) chloral

37. The IUPAC name of $CH_3—\underset{\displaystyle CH_3}{\underset{|}{C}}H—CH{=}CH—CH_3$ is
(a) 2-methylpentane (b) 4-methylpentene-2
(c) 2-hexene (d) 2,4-dimethylbutene

38. The IUPAC name of $CH_2{=}CH—CH(CH_3)_2$ is
(a) 1-isopropylethylene (b) 1,1-dimethyl-2-propene
(c) 3-methyl-1-butene (d) 2-vinylpropane

39. The IUPAC name of $CH_3CH_2\underset{\displaystyle CH_3}{\underset{|}{C}}{=}CH_2$ is

(a) 3-methylbutene-1 (b) 2-methylbutene-1
(c) vinylmethylethane (d) propylethene-1

40. The IUPAC name of $CH_3CH_2CH{=}\underset{\displaystyle CH_2CH_3}{\underset{|}{C}}{-}CH_3$ is

(a) 2-ethyl-2-pentene (b) 4-ethyl-2-pentene
(c) 3-methyl-3-hexene (d) 3-methyl-2-pentene

41. The IUPAC name of $(CH_3)_3C{-}CH{=}CH_2$ is

(a) 1,1-dimethyl-3-butene (b) 3,3-dimethyl-1-butene
(c) 3,3,3-trimethyl-1-propene (d) 1,1,1-trimethyl-2-propene

42. The IUPAC name of the compound $H_2C{=}\overset{\displaystyle CH_3}{\overset{|}{C}}{-}C{\equiv}C{-}CH_3$ is

(a) 2-methylpent-1-ene-3-yne (b) 4-methylpent-4-ene-2-yne
(c) 2-methylpent-2-ene-3-yne (d) 2-methylpent-3-yne-2-ene

43. The IUPAC name of $C_2H_5{-}\underset{\displaystyle H_2C}{\underset{\|}{C}}{-}\underset{\displaystyle CH_3}{\underset{|}{CH}}{-}CH_3$ is

(a) 3-methyl-2-ethylbutene-1 (b) 3-ethyl-3-methylbutene-1
(c) 2-ethyl-3-methylbutene-1 (d) ethylisopropylethene

44. The IUPAC name of $CH_3{-}\underset{\displaystyle CH_2CH_3}{\underset{|}{CH}}{-}CHO$ is

(a) 2-methylbutanal (b) butan-2-aldehyde
(c) 2-ethylpropanal (d) 3-methylisobutyraldehyde

45. The IUPAC name of $CH_3{-}\underset{\displaystyle CH_3}{\underset{|}{CH}}{-}CH_2{-}CH_2{-}OH$ is

(a) pentanol (b) 1-pentanol
(c) 2-methyl-4-butanol (d) 3-methyl-1-butanol

46. The IUPAC name of $CH_3CH_2\underset{\displaystyle CH_2CH_3}{\underset{|}{C}}HCH_2OH$ is

(a) 2-methyl-1-pentanol (b) 2-ethylbutanol-1
(c) 2-ethylpentanol-1 (d) 3-ethylbutanol-1

47. The IUPAC name for $CH_3CHOHCH_2-\underset{\underset{\textstyle CH_3}{|}}{\overset{\overset{\textstyle CH_3}{|}}{C}}-OH$ is

(a) 2-methyl-2,4-pentanediol
(b) 1,1-dimethyl-1,3-butanediol
(c) 1,3,3-trimethyl-1,3-propanediol
(d) 4-methyl-2,4-pentanediol

48. The IUPAC name for $CH_3-\underset{\underset{\textstyle CH_3}{|}}{CH}-CH{=}CH-CH_2-\overset{\overset{\textstyle O}{\|}}{C}-OH$ is

(a) 5-carboxy-2-methylpentene
(b) 4-isopropyl-3-butenoic acid
(c) 5-methyl-4-hexenoic acid
(d) none of these

49. The structure of 4-methylpentene-2 is

(a) $(CH_3)_2CH-CH{=}CH-CH_3$
(b) $(CH_3)_2CH-CH_2CH{=}CH_2$
(c) $(CH_3)_2CH-CH_2CH{=}CH-CH_3$
(d) $(CH_3)_2C{=}CHCH_2CH_3$

50. 2-methyl-2-butene is represented as

(a) $CH_3-\underset{\underset{\textstyle CH_3}{|}}{C}{=}CHCH_3$
(b) $CH_3-CH_2-\overset{\overset{\textstyle CH_3}{|}}{C}{=}CH_2$
(c) $CH_3-\underset{\underset{\textstyle CH_3}{|}}{CH}-CH{=}CH_2$
(d) $CH_3-\underset{\underset{\textstyle CH_2}{\|}}{C}-CH_2-CH_3$

51. The IUPAC name of $CH_3-\underset{\underset{\textstyle CH_3}{|}}{\overset{\overset{\textstyle CH_3}{|}}{C}}-Br$ is

(a) tertiary butylbromide
(b) isobutylbromide
(c) 2-bromo-2-methylpropane
(d) 2-methyl-2-propylbromide

52. The IUPAC name of $CH_3—CH{=}CHCH_2Br$ is
(a) 1-bromo-3-butene (b) 1-bromo-2-butene
(c) 2-butene-1-bromide (d) 4-bromo-2-butene

53. The IUPAC name of $(CH_3)_3C—OH$ is
(a) tert. butylalcohol (b) 2-methyl-2-propanol
(c) 2-methyl-1-butanol (d) 2-propanol

54. The IUPAC name of $CH_3COCH_2CH_2CH_3$ is
(a) methyl-*n*-propylketone (b) 2-pentanone
(c) 3-pentanone (d) *n*-propylmethylketone

55. The IUPAC name of

$$\begin{array}{lllll} & CH_3 & CH_3 & & \\ & | & | & & \\ CH_3— & C— & C— & CH_2— & CH_3 \\ & | & | & & \\ & CH_3 & CH_2CH_2CH_2CH_3 & & \end{array}$$

is

(a) 3-ethyl-2,2,3-trimethylheptane
(b) 2,2,3-trimethyl-3-*n*-butylpentane
(c) 3-methyl-3-isopropylheptane
(d) 2,2-dimethyl-3-ethyl-3-*n*-butylbutane

56. The IUPAC name of

$$\begin{array}{lllll} & & & CH_3 & \\ & & & | & \\ CH_3— & CH— & CH_2— & CH— & CH_2CH_3 \\ & | & & & \\ & CH_2CH_3 & & & \end{array}$$

is

(a) 2-ethyl-4-methylhexane (b) 3,5-dimethylheptane
(c) 5-ethyl-3-methylhexane (d) 2,4-diethylpentane

57. The IUPAC name of

$$\begin{array}{lllll} & & CH_3 & CH_3 & \\ & & | & | & \\ CH_3 & CH— & CH— & C— & CH_3 \\ & | & & | & \\ & OH & & OH & \end{array}$$

is

(a) 1,1,2-trimethyl-1,3-butanediol
(b) 1,2-dimethyl-2,4-pentanediol
(c) 2,3-dimethyl-2,4-pentanediol
(d) 1,2,3,4-tetramethyl-1,3-propanediol

58. The IUPAC name of

$$\begin{array}{lll} & CH_3 & \\ & | & \\ CH_3C{\equiv}C— & CH— & CH_3 \end{array}$$

is

(a) 4-methyl-2-pentyne (b) methylisopropylacetylene
(c) 4,4-dimethyl-2-butyne (d) 2-methyl-4-pentyne

59. The structure of 4-methyl-2-penten-1-ol is

(a) $(CH_3)_2CHCH_2{=}CHCH_2OH$

(b) $CH_3CHOH{-}CH{=}C(CH_3)_2$

(c) $(CH_3)_2{=}CHCH_2CH_2OH$

(d) $CH_3CH_2CH{=}CHCH_2OH$

60. Which of the following compounds are named correctly?

(a) $(CH_3)_2CHCH_2CH_2CH_2CHO$ (5-methyl-1-hexanal)

(b) $(CH_3)_2CHCH_2C{\equiv}C{-}COOH$ (5-methyl-2-hexynoic acid)

(c) $CH_3CH_2CH_2CH_2CH(CH_3)COOH$ (2-methylhexanoic acid)

(d) $CH_3CH_2CH{=}CH{-}COCH_3$ (3-hexen-5-one)

61. The IUPAC name of $(CH_3)_3C{-}CH_2CH{=}CH_2$ is

(a) 2,2-dimethylpent-4-ene (b) 2,2-dimethylhex-4-ene

(c) 4,4-dimethylpent-1-ene (d) hex-1-ene

62. In which of the following are all carbon atoms sp-hybridized?

(a) $CH_3{-}CH{=}CH{-}CH_3$ (b) $CH_3{-}C{\equiv}C{-}CH_3$

(c) $HC{\equiv}C{-}C{\equiv}CH$ (d) $CH_3CH_2{-}C{\equiv}CH$

63. The hybridization of carbon atoms in the C—C single bond of $HC{\equiv}C{-}CH{=}CH_2$ is

(a) sp^3–sp^3 (b) sp^2–sp^3

(c) sp–sp^2 (d) sp^3–sp

64. Which of the following compounds have only one type of hybrid carbon?

(a) $CH_2{=}CH{-}CH{=}CH_2$ (b) $HC{\equiv}C{-}C{\equiv}CH$

(c) $CH_3{-}CH_2{-}CH_2{-}CH_3$ (d) $CH_3{-}C{\equiv}C{-}CH_3$

65. In the reaction $CH_3CONH_2 \xrightarrow[\Delta]{P_2O_5} CH_3CN$, the hybridization state of the carbon atom changes from

(a) sp^2 to sp (b) sp^3 to sp

(c) sp^3 to sp^2 (d) sp^2 to sp^3

66. Which of the following have zero dipole moment?

(a) H_2 (b) HF

(c) CH_4 (d) $CHCl_3$

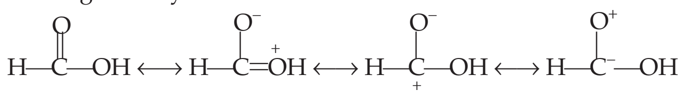
67. Arrange the following resonating structures of vinyl chloride in order of decreasing stability.

$$\underset{\text{I}}{H_2C{=}CH{-}Cl} \longleftrightarrow \underset{\text{II}}{H_2\overset{-}{C}{-}CH{=}\overset{+}{Cl}} \longleftrightarrow \underset{\text{III}}{H_2\overset{+}{C}{-}CH{=}\overset{-}{Cl}}$$

(a) I > II > III (b) III > II > I

(c) II > I > III (d) I > II = III

68. Arrange the following resonating structures of formic acid in order of decreasing stability.



I II III IV

(a) II > I > III > IV (b) I > III > II > IV

(c) III > II > IV > I (d) IV > III > I > II

69. Which of the following molecules show resonance?

(a) CO (b) CO_2

(c) NO (d) O_3

70. Arrange the following free radicals in order of stability.

$$\underset{\text{I}}{(CH_3)_3\dot{C}} \quad \underset{\text{II}}{(CH_3)_2\dot{C}H} \quad \underset{\text{III}}{CH_3\dot{C}H_2} \quad \underset{\text{IV}}{\dot{C}H_3}$$

(a) I > II > III > IV (b) IV > III > II > I

(c) II > III > I > IV (d) IV > II > III > I

71. Arrange the following free radicals in order of stability.

Benzyl, allyl, methyl, vinyl
I II III IV

(a) IV > III > II > I (b) I > II > III > IV

(c) II > IV > III > I (d) III > II > I > IV

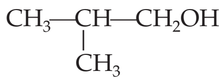
72. Arrange the following carbonium ions in order of decreasing stability.

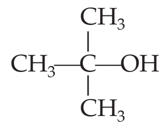
$$\underset{\text{I}}{(CH_3)_3\overset{+}{C}} \quad \underset{\text{II}}{(CH_3)_2\overset{+}{C}H} \quad \underset{\text{III}}{CH_3\overset{+}{C}H_2} \quad \underset{\text{IV}}{H_3\overset{+}{C}}$$

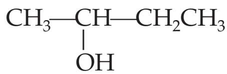
(a) II > III > I > IV (b) IV > III > II > I

(c) I > II > III > IV (d) I > II > III = IV

73. Which of the following compounds will produce the most stable carbonium ion?

(a) 

(b) 

(c) 

(d) $CH_3CH_2CH_2CH_2OH$

74. The bond that undergoes heterolytic cleavage most readily is

(a) C—C
(b) C—O
(c) C—H
(d) O—H

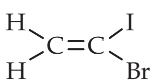
75. Hydrogen bonding is maximum in

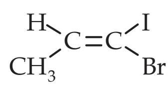
(a) triethylamine
(b) ethyl chloride
(c) ethyl alcohol
(d) diethyl ether

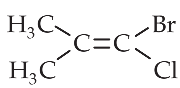
76. Which of the following compounds will exhibit cis-trans isomerism?

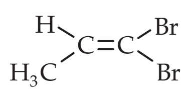
(a) 2-Butene
(b) 2-Butyne
(c) 1-Butene
(d) 2-Butanol

77. Which of the following compounds will exhibit geometrical isomerism?

(a) 

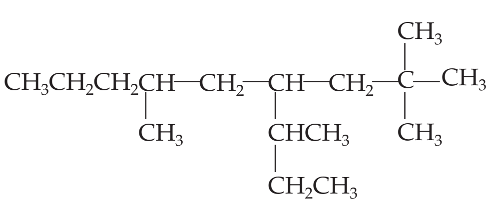
(b) 

(c) 

(d) 

78. Which of the following compounds exhibit optical isomerism?

(a) $C_2H_5OC_2H_5$
(b) $CH_3OC_3H_7$
(c) $CH_3CH_2CH_2CH_2OH$
(d) $CH_3CHOHCH_2CH_3$

79. 

The IUPAC name of this compound is

(a) 2,2,6-trimethyl-4-(1-methylpropyl) nonane
(b) 4,8,8-trimethyl-6-(1-methylpropyl) nonane
(c) 3,6-dimethyl-4-(methylene tertiary butyl) nonane
(d) 6,6-dimethyl-2-propyl-4-(1-methylpropyl) heptane

80. $CH_2{=}CH{-}\underset{\displaystyle CH_2CH_3}{\underset{|}{CH}}{-}\underset{\displaystyle Cl}{\underset{|}{C}}{=}CH_2$

The IUPAC name of this compound is

(a) 3-ethyl-4-chloro-1,4-pentadiene

(b) 2-chloro-3-ethyl-1,4-pentadiene

(c) 4-chloroethenyl-1-pentene

(d) 3-ethenyl-4-chloro-4-pentene

81. $CH_3{-}\underset{\displaystyle OCH_3}{\underset{|}{CH}}{-}\overset{\displaystyle O}{\overset{\|}{C}}{-}\underset{\displaystyle CH_3}{\underset{|}{CH}}{-}OCH_2CH_3$

The IUPAC name of this compound is

(a) 2-ethoxy-4-methoxypentan-3-one

(b) 2-methoxy-4-ethoxy-pentan-3-one

(c) 2-ethoxy-4-methoxy-pentan-3-one

(d) none of these

82. The IUPAC name of $CH_3{-}\underset{\displaystyle CH_3}{\underset{|}{CH}}{-}\underset{\displaystyle CH_3}{\underset{|}{CH}}{-}CH_2{-}CHO$ is

(a) 2,3-dimethylpentanal (b) 3,4-dimethylpentanal

(c) 3,4,4-trimethylbutanal (d) 3-isopropylbutanal

83. The IUPAC name of $CH_3{-}\underset{\displaystyle OH}{\underset{|}{CH}}{-}CH_2{-}\underset{\displaystyle OH}{\underset{|}{C}}(CH_3)_2$ is

(a) 2-methyl-2,4-dihydroxypropane

(b) 2,2-dimethyl-4-hydroxybutanol

(c) 2-methyl-2,4-pentanediol

(d) 2-hydroxy-4,4-dimethylbutanol-4

84. The IUPAC name of $BrCH_2{-}\underset{\displaystyle CONH_2}{\underset{|}{CH}}{-}CO{-}CH_2{-}CH_2CH_3$ is

(a) 2-bromomethyl-3-oxohexanamide

(b) 1-bromo-2-amido-3-oxohexane

(c) 1-bromo-2-amido-*n*-propylketone

(d) 3-bromo-2-proponyl-propanamide

85. The IUPAC name of $CH_3-CH_2-\underset{\displaystyle CH_3}{\underset{|}{CH}}-COOC_2H_5$ is

(a) 2-ethyl-ethylacetate
(b) ethyl 3-methylbutanoate
(c) ethyl 2-methylbutanoate
(d) 2-methylbutanoic acid ethylester

86. The IUPAC name of $CH_3CH_2-\underset{\displaystyle CH_3}{\underset{|}{N}}-CH_2CH_3$ is

(a) N-methyl-N-ethylethylamine
(b) diethylmethylamine
(c) N-ethyl-N-methylaminoethane
(d) methyldiethylamine

87. $CH_3-CH_2-\overset{\displaystyle CHO}{\overset{|}{CH}}-\underset{\displaystyle CH_3}{\underset{|}{CH}}-CH_3$

The IUPAC name of this compound is

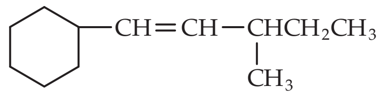
(a) 2-isopropylbutanal
(b) 2-ethyl-3-methylbutanal
(c) 3-ethyl-2-methylbutanal
(d) 2-methylpentane-3-aldehyde

88. The IUPAC name of $C_6H_5-\underset{\displaystyle C_6H_5}{\underset{|}{CH}}-CH_2-CCl_3$ is

(a) 1,1,1-trichloro-3,3-diphenylpropane
(b) 1,1-diphenyl-3,3,3-trichloropropane
(c) (a) as well as (b)
(d) none of these

89. The IUPAC name of $C_6H_5CH{=}CH-COOH$ is
(a) cinnamic acid
(b) 1-phenyl-2-carboxyethene
(c) 3-phenylprop-2-enoic acid
(d) dihydro-3-phenylpropionic acid

90. The IUPAC name of $HC{\equiv}CCH_2CH{=}CH_2$ is
(a) 1-propyn-ethene
(b) propeneacetylene
(c) pent-4-yne-1-ene
(d) pent-1-en-4-yne

91. The IUPAC name of  is

(a) 1-cyclohexyl-3-methyl-1-pentene

(b) 3-methyl-5-cyclohexyl-pent-1-ene

(c) 1-cyclohexyl-3-ethyl-but-1-ene

(d) 1-cyclohexyl-3,4-dimethyl-but-1-ene

92. $$\begin{array}{ccccc} & & CH_2CH_3 & & & \\ & & | & & & \\ CH_3 & — & C & — & CH & — & CH_3 \\ & & | & & | & & \\ & & CH_3 & & OH & & \end{array}$$

The IUPAC name of this compound is

(a) 3,3-dimethyl-2-pentanol

(b) 3-methyl-3-ethyl-2-butanol

(c) 3,3-dimethyl-3-ethyl-isopropanol

(d) 3,3-dimethyl-3-ethyl-2-hydroxypropane

93. $$\begin{array}{ccccccc} & & F & & Cl & & \\ & & | & & | & & \\ CH_3 & — & C & — CH_2 — & C & — & CH_3 \\ & & | & & | & & \\ & & CH_2CH_3 & & CH_2CH_3 & & \end{array}$$

The IUPAC name of this compound is

(a) 2-fluoro-4-chloro-2,4-diethylpentane

(b) 3-fluoro-5-chloro-3-methyl-5-ethylhexane

(c) 3-chloro-5-fluoro-3,5-dimethylheptane

(d) 3,5-dimethyl-5-fluoro-3-chloroheptane

94. The —I effect of $—NO_2$, —CN, —COOH, —Cl decreases in the order

(a) $—NO_2 > —CN > —COOH > —Cl$

(b) $—Cl > —COOH > —CN > —NO_2$

(c) $—CN > —NO_2 > —Cl > —COOH$

(d) $—COOH > —CN > —NO_2 > —Cl$

95. The +I effect of $(CH_3)_3C$(I), $(CH_3)_2CN$(II), $CH_3C—H_2$(III), CH_3(IV) decreases in the order

(a) I > II > III > IV

(b) IV > III > II > I

(c) II > I > IV > III

(d) I > II > IV > III

96. The inductive effect of the alkyl groups on a saturated carbon chain follows the order

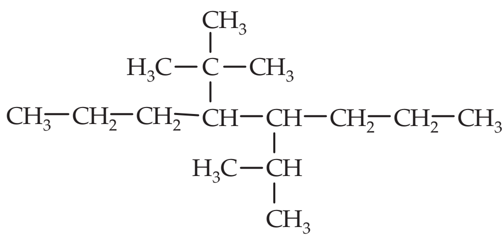
(a) $(CH_3)_3\,C— > (CH_3)_2\,CH—> CH_3–CH_2— > CH_3—$

(b) $CH_3— > CH_3—CH_2— > (CH_3)_2CH— > (CH_3)_3C—$

(c) $CH_3\,CH_2— > CH_3— > (CH_3)_3C— > (CH_3)_2CH—$

(d) $(CH_3)_2CH— > (CH_3)_3C— > CH_3— > CH_3CH_2—$

97. Give the IUPAC name of



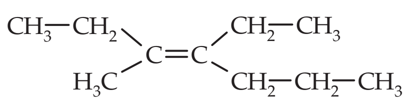
(a) 4-isopropyl-5-tert. butyloctane

(b) 4-tert. butyl-5-isopropyloctane

(c) 2-methyl-3-propyl-4-tert. butylheptane

(d) 2, 2-dimethyl-3-propyl-4-isopropylheptane

98. The IUPAC name of



is

(a) 4-ethyl-3-methyl-*trans*-3-heptene

(b) 4-ethyl-5-methyl-*trans*-4-heptene

(c) 3-methyl-4-propyl-3-hexene

(d) 3-propyl-4-ethyl-3-pentene

99. The IUPAC name of $ClCH_2CH{=}\overset{\overset{\displaystyle CH_2CH_3}{|}}{C}CH_2—OH$ is

(a) 5-chloro-3-penten-3-carbinol

(b) 1-chloro-3-penten-3-carbinol

(c) 4-chloro-2-ethyl-2-buten-1-ol

(d) 1-chloro-3-ethyl-2-buten-4-ol

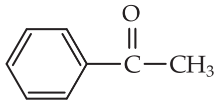
100. The IUPAC name of $CH_2{=}\overset{\overset{\displaystyle CH_3}{|}}{C}—CHO$ is

(a) methacrolein

(b) methacrylaldehyde

(c) 2-methylpropenal

(d) propenaldehyde

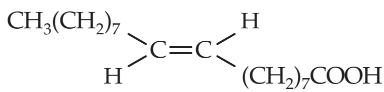
101. The IUPAC name of  is

(a) phenylethanone (b) methylphenylketone
(c) acetophenone (d) phenylemethylketone

102. The IUPAC name of $HC\equiv C-C\equiv C-\overset{C\equiv CH}{\overset{|}{C}}HCH_2-CH_3$ is

(a) 5-ethyl-1,3, 6-heptatriyne (b) 3-ethyl-2,4, 5-heptatriyne
(c) 5-ethenyl-1,3-heptatriyne (d) 3-ethenyl-4,6-heptatriyne

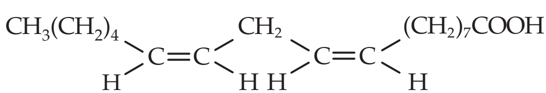
103. The IUPAC name of



is

(a) elaidic acid (b) *trans*-octadec-9-enoic acid
(c) dihydrosteric acid (d) oleic acid

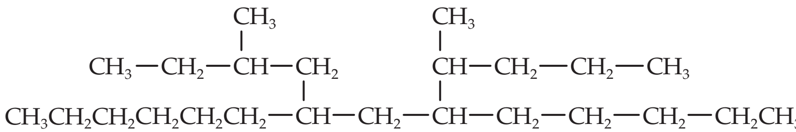
104. The IUPAC name of



is

(a) *cis-cis*-9,12-octadecadienoic acid
(b) *cis-trans*-9,12-octadecadienoic acid
(c) 9,10-octadecadienoic acid
(d) 9,14-octadecadienoic acid

105. The IUPAC name of



is

(a) 6-(1-methylbutyl)-8-(2-methylbutyl) tetradecane
(b) 6-(2-methylbutyl)-8-(1-methylbutyl) tetradecane
(c) 4-methyl-5-*n*-pentyl-7-(2-methylbutyl) tridecane
(d) 3-methyl-5-*n*-hexyl-7-(1-methylbutyl) didecane

106. The IUPAC name of $OHC{-}CH_2{-}CH_2{-}\overset{\overset{\displaystyle CH_2{-}CHO}{|}}{CH}{-}CH_2{-}CHO$ is

(a) 4, 4-di(formylmethyl) butanal

(b) 2-(formylmethyl) butane-1,4-dicarbaldehyde

(c) hexane-3-acetal-1,6-dial

(d) 3-(formylmethyl) hexane-1,6-dial

107. The IUPAC name of

$$HOOC{-}CH_2{-}CH_2{-}\overset{\overset{\displaystyle COOH}{|}}{CH}{-}CH_2CH_2{-}COOH$$

is

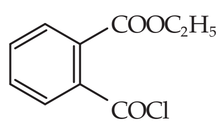
(a) 4-carboxyheptane-1,7-dioic acid

(b) 3-propionyl-propane-1,3-dioic acid

(c) pentane-1,3, 5-tricarboxylic acid

(d) 4-methionate butane-1,3-dioic acid

108. The IUPAC name of



is

(a) 2-chlorocarbonyl ethylbenzoate

(b) 2-carboxyethyl benzoyl chloride

(c) ethyl-2-(chlorocarbonyl) benzoate

(d) ethyl-1-(chlorocarbonyl) benzoate

109. The IUPAC name of C_6H_5CN is

(a) phenyl cyanide (b) phenylacetonitrile

(c) benzene cyanide (d) benzonitrile

110. The IUPAC name of $C_6H_5CH_2CH_2NH_2$ is

(a) β-phenylethylamine (b) 2-phenylaminoethane

(c) 2-phenylethanamine (d) benzyl methylamine

111. The IUPAC name of $CH_3{-}NH{-}\underset{\underset{\displaystyle CH_3}{|}}{CH}{-}CH_2{-}\underset{\underset{\displaystyle CH_3}{|}}{CH}{-}CH_3$ is

(a) 2-(n-methylamino)-4-methylpentane

(b) n,4-dimethylpentan-2-amine

(c) 2-(n-methylamino)-3-isopropylpropane

(d) 2-(n-methylamino)-1,4,4-trimethylbutane

Answers

1. c	**2.** a	**3.** a	**4.** c	**5.** c
6. d	**7.** c	**8.** d	**9.** d	**10.** c
11. b	**12.** a	**13.** b	**14.** c	**15.** a
16. a	**17.** d	**18.** d	**19.** a	**20.** c
21. a, b, c	**22.** c	**23.** c	**24.** c, d	**25.** a, d
26. a	**27.** c	**28.** c	**29.** c	**30.** b
31. a	**32.** c	**33.** d	**34.** b	**35.** a
36. b	**37.** b	**38.** c	**39.** b	**40.** c
41. b	**42.** a	**43.** c	**44.** a	**45.** d
46. b	**47.** a	**48.** d	**49.** a	**50.** a
51. c	**52.** b	**53.** b	**54.** b	**55.** a
56. b	**57.** c	**58.** a	**59.** a	**60.** a, b, c
61. c	**62.** c	**63.** c	**64.** a, b, c	**65.** a
66. a, c	**67.** a	**68.** b	**69.** a, b, c, d	**70.** a
71. b	**72.** c	**73.** b	**74.** d	**75.** c
76. a	**77.** b	**78.** d	**79.** a	**80.** b
81. a	**82.** b	**83.** c	**84.** a	**85.** c
86. a	**87.** b	**88.** a	**89.** c	**90.** d
91. a	**92.** a	**93.** c	**94.** a	**95.** a
96. a	**97.** b	**98.** a	**99.** c	**100.** c
101. a	**102.** a	**103.** b	**104.** a	**105.** a
106. d	**107.** c	**108.** c	**109.** d	**110.** c
111. b				

Hints to More Difficult Problems

2 & 6 Compounds of this type are named systematically by attaching the prefix 'bicyclo' to the name of the open-chain hydrocarbon with the same total number of carbon atoms in the ring. The size of the two rings is specified by the number of carbon atoms in each of the three linkages which connect the two atoms at the ring junctions.

15. According to IUPAC nomenclature, the name is assigned by taking the longest continuous chain as it passes through the double bond.

❑

2

Reaction Mechanisms

• *Type 1* •

Choose the correct option. Only one option is correct.

1. The nucleophilicities of R_3C^-, R_2N^-, RO^- and F^- decrease in the order
(a) $R_3C^- > R_2N^- > RO^- > F^-$ (b) $F^- > RO^- > R_2N^- > R_3C^-$
(c) $RO^- > F^- > R_2N^- > R_3C^-$ (d) $R_3C^- > RO^- > F^- > R_2N^-$

2. The nucleophilicities of RO^-, HO^-, $RCOO^-$, ROH and H_2O are of the order
(a) $HO^- > RO^- > H_2O > ROH > RCOO^-$
(b) $RO^- > HO^- > RCOO^- > ROH > H_2O$
(c) $H_2O > ROH > RCOO^- > HO^- > RO^-$
(d) $ROH > H_2O > HO^- > RCOO^- > RO^-$

3. The order of leaving group ability for halides is
(a) $Cl^- > Br^- > I^- > F^-$ (b) $F^- > Br^- > I^- > Cl^-$
(c) $Br^- > Cl^- > F^- > I^-$ (d) $I^- > Br^- > Cl^- > F^-$

4. The hydrolysis of tert. butylchloride follows
(a) first-order kinetics (b) second-order kinetics
(c) pseudo first-order kinetics (d) none of these

5. The order of basicity of halides is
(a) $Cl^- < Br^- < I^- < F^-$ (b) $F^- < I^- < Br^- < Cl^-$
(c) $I^- < Br^- < Cl^- < F^-$ (d) $Cl^- < F^- < I^- < Br^-$

6. The hydrolysis of 2-bromo-3-methylbutane yields
(a) 2-methyl-2-butanol (b) 2-methyl-3-butanol
(c) a mixture of (a) and (b) (d) none of these

7. The stability of $\overset{\circ}{1}, \overset{\circ}{2}, \overset{\circ}{3}$ and benzyl carbocations is of the order

(a) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3} >$ benzyl
(b) benzyl $> \overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1}$
(c) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1} >$ benzyl
(d) $\overset{\circ}{3} >$ benzyl $> \overset{\circ}{2} > \overset{\circ}{1}$

8. The order of reactivity of alkyl halides is

(a) tert. alkyl halides > allyl halides > sec. alkyl halides > primary alkyl halides
(b) primary alkyl halides > sec. alkyl halides > tert. alkyl halides > allyl halides
(c) allyl halides > primary alkyl halides > sec. alkyl halides > tert. alkyl halides
(d) sec. alkyl halides > primary alkyl halides > tert. alkyl halides > allyl halides

9. Which of the following hydrolyses the fastest?

(a) CH_3Cl
(b) CH_3CH_2Cl
(c) CH_3OCH_2Cl
(d) $(CH_3)_2CHCl$

10. Which of the following alkyl halides would be the most reactive in an S_N2 reaction?

(a) $C_6H_5CH_2CH_2CH_2Br$
(b) $\begin{array}{l} C_6H_5\underset{\displaystyle CH_3}{\underset{|}{C}}HCH_2Br \end{array}$
(c) $C_6H_5\overset{\displaystyle CH_3}{\overset{|}{\underset{\displaystyle CH_3}{\underset{|}{C}}}}\text{—}Br$
(d) $C_6H_5CH_2\underset{\displaystyle Br}{\underset{|}{C}}HCH_3$

11. Which of the following alkyl halides would be the most reactive in an S_N1 reaction?

(a) $C_6H_5CH_2CH_2CH_2Br$
(b) $C_6H_5\underset{\displaystyle CH_3}{\underset{|}{C}}H\text{—}CH_2Br$
(c) $C_6H_5\overset{\displaystyle CH_3}{\overset{|}{\underset{\displaystyle CH_3}{\underset{|}{C}}}}\text{—}Br$
(d) $C_6H_5CH_2\underset{\displaystyle Br}{\underset{|}{C}}HCH_3$

12. Arrange NO_2, F, COOH, Cl, OH, OR and C_6H_5 in order of electron-withdrawing effect.

(a) $F > NO_2 > COOH > OH > Cl > OR > C_6H_5$
(b) $COOH > NO_2 > F > Cl > OH > C_6H_5 > OR$
(c) $C_6H_5 > OR > Cl > OH > COOH > NO_2 > F$
(d) $NO_2 > F > COOH > Cl > OH > OR > C_6H_5$

13. Arrange the groups CH_3—, CH_3CH_2—, $(CH_3)_2CH$— and $(CH_3)_3C$— in order of electron-releasing effect.

(a) $(CH_3)_3C\text{—} > (CH_3)_2CH\text{—} > CH_3CH_2\text{—} > CH_3\text{—}$

(b) $CH_3\text{—} > CH_3CH_2\text{—} > (CH_3)_2CH\text{—} > (CH_3)_3C\text{—}$

(c) $CH_3CH_2\text{—} > CH_3\text{—} > (CH_3)_3C\text{—} > (CH_3)_2CH\text{—}$

(d) $(CH_3)_2CH\text{—} > (CH_3)_3C\text{—} > CH_3\text{—} > CH_3CH_2\text{—}$

14. The order of the —I effect orbitals is

(a) $sp^3 > sp^2 > sp$ (b) $sp^2 > sp^3 > sp$

(c) $sp > sp^2 > sp^3$ (d) $sp^3 > sp > sp^2$

15. The hyperconjugative effect of the group R in R–CH=CH_2, where R is CH_3–, CH_3CH_2– or $(CH_3)_2CH$, follows the order

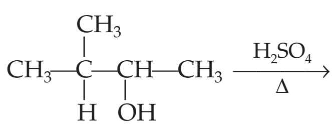
(a) $CH_3\text{–} > CH_3CH_2\text{–} > (CH_3)_2CH\text{–}$

(b) $(CH_3)_2CH\text{–} > CH_3CH_2\text{–} > CH_3\text{–}$

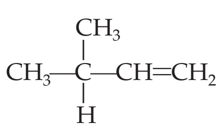
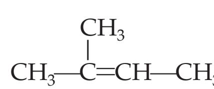
(c) $CH_3\text{–} > (CH_3)_2CH\text{–} > CH_3CH_2\text{–}$

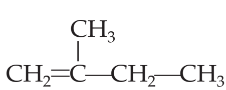
(d) $(CH_3)_2CH\text{–} > CH_3\text{–} > CH_3CH_2\text{–}$

16. The product obtained in the reaction

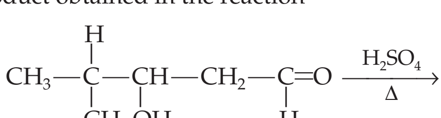


is

(a)    (b) 

(c)    (d) none of these

17. The major product obtained in the reaction



is

(a) $CH_3-\underset{\underset{CH_3}{|}}{C}=CH-CH_2-\underset{\underset{H}{|}}{C}=O$

(b) $CH_3-\underset{\underset{CH_3}{|}}{CH}-CH=CH-\underset{\underset{H}{|}}{C}=O$

(c) $CH_2=\underset{\underset{CH_3}{|}}{CH}-CH_2-CH_2-\underset{\underset{H}{|}}{C}=O$

(d) none of these

18. Arrange the acids CH_3CH_2COOH(I), $CH_2{=}CH{-}COOH$(II) and $HC{\equiv}C{-}COOH$(III) in order of decrease in acidity.

(a) I > II > III (b) III > II > I (c) II > I > III (d) III > I > II

19. The order of stability of the carbon radicals $\overset{\circ}{3}$, $\overset{\circ}{2}$, $\overset{\circ}{1}$ and $\dot{C}H_3$ is

(a) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3} > \dot{C}H_3$ (b) $\dot{C}H_3 > \overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3}$

(c) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1} > \dot{C}H_3$ (d) $\dot{C}H_3 > \overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1}$

20. The order of stability of the carbocations $\overset{\circ}{1}$, $\overset{\circ}{2}$, $\overset{\circ}{3}$ and $\overset{\oplus}{C}H_3$ is

(a) $\overset{\oplus}{C}H_3 > \overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3}$ (b) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3} > \overset{\oplus}{C}H_3$

(c) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\oplus}{C}H_3 > \overset{\circ}{3}$ (d) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1} > \overset{\oplus}{C}H_3$

21. The reaction of *cis*-2-butene with bromine gives

(a) meso dibromide
(b) racemic dibromide
(c) a mixture of meso and racemic dibromide
(d) none of these

22. In the reaction

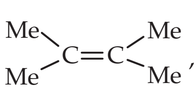
$$(CH_3)_2CH{-}CH{=}CH_2 \xrightarrow{HCl}$$

the product obtained is

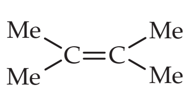
(a) $(CH_3)_2CCl{-}CH_2CH_3$ (b) $(CH_3)_2CH-\underset{\underset{Cl}{|}}{CH}-CH_3$

(c) a mixture of (a) and (b) (d) none of these

23. The relative rates of addition of



I



II

$CH_3CH_2CH{=}CH_2$, $CH_2{=}CH_2$

III IV

and $\underset{(V)}{CH_2{=}CH{-}COOH}$ follow the order

(a) I > II > III > IV > V
(b) V > IV > III > II > I
(c) II > III > I > IV > V
(d) IV > III > II > V > I

24. The conjugation of electron-withdrawing groups

$$\text{(e.g., } -CHO,\ -\overset{O}{\overset{\|}{C}}-R,\ -\overset{O}{\overset{\|}{C}}-OR,\ -C{\equiv}N \text{ and } -NO_2)$$

activates nucleophilic addition. The order of reactivity of these groups is

(a) $-NO_2 > -C{\equiv}N > \overset{O}{\overset{\|}{C}}-OR > -\overset{O}{\overset{\|}{C}}-R > -\overset{O}{\overset{\|}{C}}-H$

(b) $-\overset{O}{\overset{\|}{C}}-H > -\overset{O}{\overset{\|}{C}}-R > -\overset{O}{\overset{\|}{C}}-OR > -C{\equiv}N > NO_2$

(c) $-C{\equiv}N > -NO_2 > -\overset{O}{\overset{\|}{C}}-H > -\overset{O}{\overset{\|}{C}}-R > -\overset{O}{\overset{\|}{C}}-OR$

(d) $-\overset{O}{\overset{\|}{C}}-H > -NO_2 > -C{\equiv}N > -\overset{O}{\overset{\|}{C}}-OR > -\overset{O}{\overset{\|}{C}}-R$

25. The order of hydrolysis of the alkyl halides (allyl, $\overset{\circ}{3}$, $\overset{\circ}{2}$, $\overset{\circ}{1}$, CH_3X) by the S_N1 path is

(a) allyl > $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1} > CH_3X$
(b) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3}$ > allyl > CH_3X
(c) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3} > CH_3X$ > allyl
(d) $CH_3X > \overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3}$ > allyl

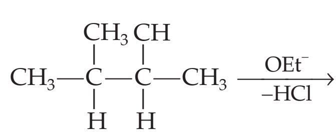
26. The rate of hydrolysis of alkyl halides 1°, 2°, 3° and CH_3X by the S_N2 path is

(a) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3} > CH_3X$
(b) $CH_3X > \overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1}$
(c) $CH_3X > \overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3}$
(d) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1} > CH_3X$

27. The order of elimination of halogens in $\overset{\circ}{1}$, $\overset{\circ}{2}$ and $\overset{\circ}{3}$ alkyl halides is

(a) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3}$
(b) $\overset{\circ}{3} > \overset{\circ}{1} > \overset{\circ}{2}$
(c) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1}$
(d) $\overset{\circ}{2} > \overset{\circ}{3} > \overset{\circ}{1}$

28. The major product obtained in the reaction



is

(a) $CH_3-\overset{\overset{\displaystyle CH_3}{|}}{C}=CH-CH_3$ (b) $CH_3-\overset{\overset{\displaystyle CH_3}{|}}{C}-CH=CH_2$

(c) $CH_2=\overset{\overset{\displaystyle CH_3}{|}}{C}-CH_2-CH_3$ (d) none of these

29. The major product obtained in the reaction

$$(CH_3)_3C-CH_2-\underset{\underset{\displaystyle CH_3}{|}}{\overset{\overset{\displaystyle CH_3}{|}}{C}}-Br \xrightarrow[-HBr]{OEt^-}$$

is

(a) $(CH_3)C-CH=\overset{\overset{\displaystyle CH_3}{|}}{C}-CH_3$ (b) $(CH_3)_3C-CH_2-\overset{\overset{\displaystyle CH_3}{|}}{C}=CH_2$

(c) $CH_3-\underset{\underset{\displaystyle CH_3}{|}}{\overset{\overset{\displaystyle CH_3}{|}}{C}}-CH_2-\overset{\overset{\displaystyle CH_3}{|}}{CH}-CH_3$ (d) none of these

30. The elimination reaction

$$CH_3-CH_2\cdot\underset{\underset{\displaystyle {}^{\oplus}NMe_3}{|}}{CH}-CH_3 \xrightarrow{\Delta} \underset{\text{(major)}}{CH_3CH_2-CH=CH_2}$$

is governed by

(a) the Saytzev rule

(b) the Hofmann rule

(c) the Saytzev as well as the Hofmann rule

(d) neither

31. The diazotization of $CH_3CH_2CH_2CH_2NH_2$ with $NaNO_2$ and dilute HCl at 0–5°C followed by the warming of the solution gives the following major product.

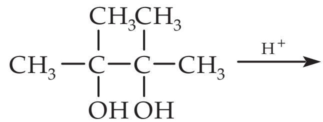
(a) 1-Butanol

(b) 2-Butanol

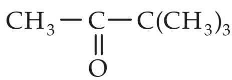
(c) An equimolecular mixture of these

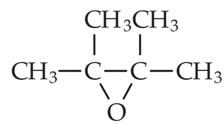
(d) None of these

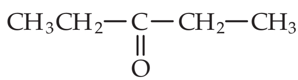
32. In the reaction



the product obtained is

(a) 

(b) 

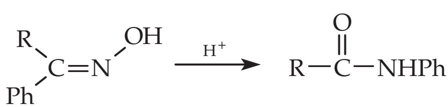
(c) 

(d) none of these

33. The reaction of cyclobutylamine with sodium nitrite and dilute HCl at 0–5°C followed by warming gives

(a) only cyclobutanol
(b) only cyclopropylcarbinol
(c) a mixture of cyclobutanol and cyclopropylcarbinol
(d) none of these

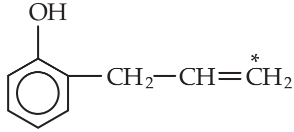
34. The reaction

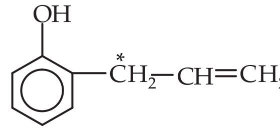


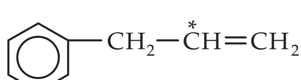
is a case of

(a) Curtius rearrangement
(b) Hofmann rearrangement
(c) Schmidt reaction
(d) Beckmann rearrangement

35. Phenylallylether, $C_6H_5O\overset{*}{C}H_2-CH=CH_2$, in which the carbon atom next to O is ^{14}C, on being heated to 200°C, gives

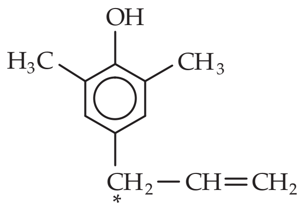
(a) 

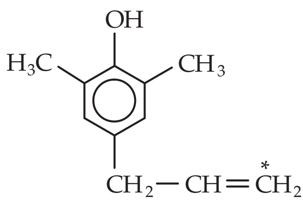
(b) 

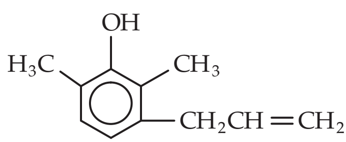
(c) 

(d) none of these

36. 2,4-Dimethylphenylallyl ether, in which the carbon atom next to the oxygen is ^{14}C, on being heated to 200°C, gives

(a) 

(b) 

(c) 

(d) none of these

37. On heating phenylacetate in the presence of anhydrous aluminium chloride, we obtain

(a) only *o*-hydroxy acetophenone

(b) only *p*-hydroxy acetophenone

(c) a mixture of *o*- and *p*-hydroxy acetophenone

(d) none of these

38. The reaction of acetaldehyde with an excess of formaldehyde gives

(a) $\begin{array}{l} H_2C{-}OH \\ \;\;| \\ \;\;CH_2CHO \end{array}$

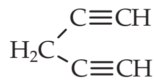
(b) $\begin{array}{ccc} & CH_2OH & \\ & | & \\ HOH_2C - & C & - CHO \\ & | & \\ & CH_2OH & \end{array}$

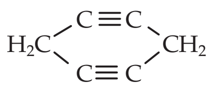
(c) $\begin{array}{ccc} & CH_2OH & \\ & | & \\ HOH_2C - & C & - CH_2OH \\ & | & \\ & CH_2OH & \end{array}$

(d) none of these

39. The condensation of acetylene with formaldehyde in the presence of Cu_2C_2 gives

(a) $HOH_2C–C{\equiv}C–CH_2OH$

(b) 

(c) 

(d) none of these

40. The reaction of an acid chloride with diazomethane followed by treatment with water gives a carboxylic acid. The reaction occurs through the intermediate formation of

(a) carbene
(b) ketene
(c) benyne
(d) a carbocation

41. In the Baeyer–Villiger rearrangement, the group that migrates (in case of unsymmetrical ketones) is the one which is more electron-releasing. The aptitude of migration of the alkyl groups is of the order

(a) $1^\circ > 2^\circ > 3^\circ > CH_3$
(b) $CH_3 > 3^\circ > 2^\circ > 1^\circ$
(c) $CH_3 > 1^\circ > 2^\circ > 3^\circ$
(d) $3^\circ > 2^\circ > 1^\circ > CH_3$

42. In the Baeyer–Villiger oxidation of alkyl aryl ketones, it is the more electron-releasing group that migrates. The aptitude of migration of the aryl groups is of the order

(a) *p*-chlorophenyl > *p*-anisyl > *p*-tolyl > phenyl
(b) phenyl > *p*-tolyl > *p*-anisyl > *p*-chlorophenyl
(c) *p*-anisyl > *p*-tolyl > phenyl > *p*-chlorophenyl
(d) *p*-chlorophenyl > phenyl > *p*-tolyl > *p*-anisyl

43. On treatment with NaOH an oxime of 2-bromo-5-nitroacetophenone did not undergo any change. However, on subjecting it to Beckmann rearrangment, N-(2-bromo-5-nitrophenyl) acetamide was obtained. On the basis of these observations, it may be concluded that the starting oxime has

(a) only an anti- or *trans*-structure
(b) only a syn- or *cis*-structure
(c) a mixture of syn- and anti-oximes
(d) none of these

44. The major product obtained in the reaction

$$NC{—}CH{=}CH_2 \xrightarrow{HBr}$$

is

(a) $NC-\underset{\underset{Br}{|}}{CH}-CH_3$

(b) $NC—CH_2—CH_2Br$

(c) an equimolecular mixture of (a) and (b)

(d) none of these

45. In the reaction

$$(CH_3)_3CCH{=}CH_2 \xrightarrow{HCl}$$

the product obtained is

(a) Only $(CH_3)_3-\underset{\underset{Cl}{|}}{CH}-CH_3$ (b) Only $(CH_3)_2-\underset{\underset{Cl}{|}}{C}-CH(CH_3)_2$

(c) a mixture of (a) and (b) (d) none of these

46. The reaction

$$CH_3CH{=}CH_2 + HBr \xrightarrow{\text{peroxide}} CH_3CH_2CH_2Br$$

can be explained by

(a) carbocation formation (b) free-radical mechanism

(c) carboanion formation (d) none of these

47. The product obtained in the reaction

$$CH_3CH{=}CH_2 \xrightarrow[\text{benzoyl peroxide}]{HCl} \text{is}$$

(a) $CH_3\underset{\underset{Cl}{|}}{CH}-CH_3$ (b) $CH_3CH_2CH_2Cl$

(c) $CH_3CH_2CH_2CH_2CH_2CH_3$ (d) none of these

48. Maleic anhydride undergoes a Diels-Alder reaction with

(a) benzene (b) naphthalene

(c) phenanthrene (d) anthracene

49. In the Friedel–Crafts reaction of an aromatic compound with an alkyl halide or acid halide in the presence of a catalyst, the order of reactivity of the following catalysts is

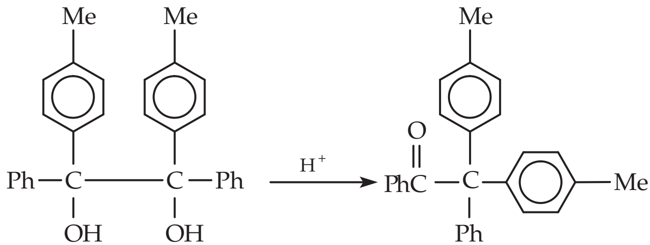
(a) $AlBr_3 > AlCl_3 > FeCl_3 > SbCl_5 > BCl_3 > BF_3$

(b) $AlCl_3 > FeCl_3 > AlBr_3 > SbCl_5 > BF_3 > BCl_3$

(c) $BF_3 > BCl_3 > SbCl_5 > FeCl_3 > AlCl_3 > AlBr_3$

(d) $FeCl_3 > AlCl_3 > AlBr_3 > SbCl_5 > BF_3 > BCl_3$

50. In the pinacol-pinacoline rearrangement



the trend of migration among the aryl groups is

(a) *p*-anisyl > *p*-tolyl > phenyl > *p*-chlorophenyl

(b) *p*-chlorophenyl > phenyl > *p*-tolyl > *p*-anisyl

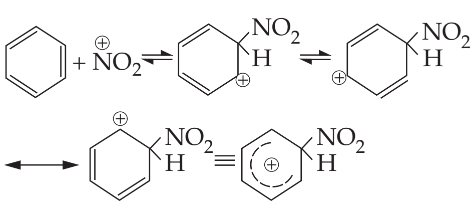
(c) phenyl > *p*-tolyl > *p*-anisyl > *p*-chlorophenyl

(d) *p*-tolyl > *p*-anisyl > *p*-chlorophenyl > phenyl

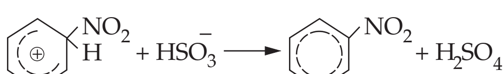
51. In the nitration of benzene with concentrated HNO_3 and concentrated H_2SO_4, which of the following is the rate- determining step?

(a) $$HO-NO_2 + H_2SO_4 \rightleftharpoons H_2\overset{\oplus}{O}-NO_2 + H\overset{\ominus}{SO_4}$$
$$\xrightleftharpoons{H_2SO_4} H_3\overset{\oplus}{O} + \overset{\oplus}{N}O_2 + 2H\overset{\ominus}{SO_4}$$

(b)



(c)



(d) none of these

52. Arrange the following radicals in order of decreasing stability.

I: $(CH_3)_3\dot{C}$

II: $CH_2{=}CH{-}\dot{C}(CH_3)_2$

III: $\dot{C}H_3$

IV: $(CH_3)_2CH\dot{C}H_2$

V: $(CH_3)_2\dot{C}H$

(a) I, II, III, IV, V (b) V, I, III, IV, II

(c) II, I, V, IV, III (d) II, V, I, III, V

53. Among the following, which is the strongest nucleophile for an S_N2 reaction?

(a) H_2O (b) RCO_2^- (c) OH^- (d) RO^-

54. The weakest nucleophile in an aprotic solvent is

(a) I^- (b) Br^- (c) Cl^- (d) F^-

55. The prerequisite for an S_N2 reaction is

(a) a carbocation
(b) a carbanion
(c) a penta-coordinated transition state
(d) none of these

56. The addition of KI increases the rate of the reaction.

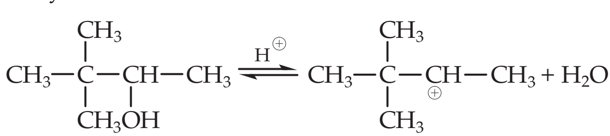
$$CH_3CH_2Cl + H_2O \longrightarrow CH_3CH_2OH + HCl$$

This is because I^- is a

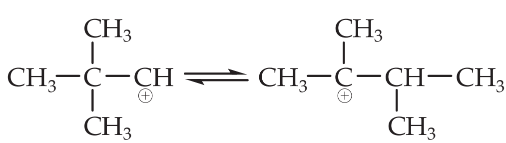
(a) a good nucleophile and a good leaving group
(b) a poor nucleophile and a poor leaving group
(c) a poor nucleophile and a good leaving group
(d) none of these

57. The rate-determining step in the acid catalysed dehydration of 3,3-dimethyl-2-butanol is

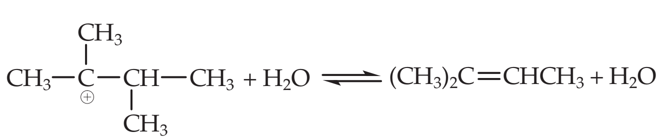
(a)



(b)



(c)



(d) none of these

58. Arrange H_2O, $HC\equiv CH$, NH_3 and CH_3CH_3 in order of acidity.

(a) $H_2O > HC\equiv CH > NH_3 > CH_3CH_3$
(b) $HC\equiv CH > H_2O > NH_3 > CH_3CH_3$
(c) $CH_3CH_3 > HC\equiv CH > NH_3 > H_2O$
(d) $H_2O > NH_3 > HC\equiv CH > CH_3CH_3$

59. In which of the following reactions are free-radical intermediates obtained?

(a) $CH_3CH{=}CH_2 + HBr \longrightarrow CH_3\underset{\substack{|\\ Br}}{C}HCH_3$

(b) $CH_3\underset{\substack{|\\ OH}}{C}H{-}CH_3 + H_2SO_4 \longrightarrow CH_3CH{=}CH_2 + H_2O$

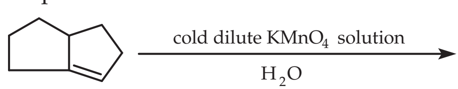
(c) $CH_2{=}CHCH_3 + Hg(OAc)_2 \longrightarrow CH_3{-}\underset{\substack{|\\ OH}}{C}{-}CHCH_2OAc + CH_3COOH$

(d) $CH_3CH{=}CH_2 + HBr \xrightarrow{R-O-O-R} CH_3CH_2CH_2Br$

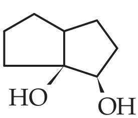
60. The Markovnikov addition of HCl to propene involves the

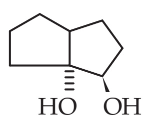
(a) initial attack of a chloride ion
(b) isomerization of 1-chloropropane
(c) formation of an *n*-propyl cation
(d) formation of an isopropyl cation

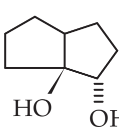
61. The product expected in the reaction

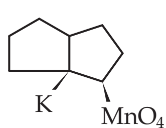


is

(a)


(b)


(c)


(d)


62. The reaction of 1-hexene with HBr in the presence of peroxides yields 1-bromohexane. The mechanism of the reaction involves the attack on the alkene by

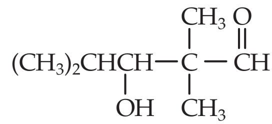
(a) a Br^+ ion
(b) a bromide ion
(c) a bromine atom
(d) an $R\dot{O}$ radical

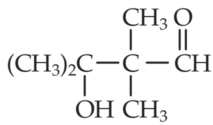
63. Which of the following methods of preparing alcohol proceed via anti-Markovnikov addition?

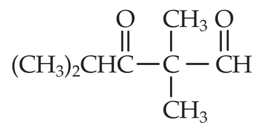
(a) Acid-catalysed hydration
(b) Oxymercuration-demercuration
(c) Hydroboration-oxidation
(d) None of these

64. The aldol condensation of $(CH_3)_2CH{-}\overset{O}{\overset{\|}{C}}H$ gives

(a) $(CH_3)_2CHCH_2OH$

(b) 

(c) 

(d) 

65. Phorone, $(CH_3)_2C{=}CH{-}\overset{O}{\overset{\|}{C}}{-}CH{=}C(CH_3)_2$, can be made through aldol condensation and the subsequent dehydration of

(a) 3 moles of acetone

(b) 3 moles of acetaldehyde

(c) 2 moles of acetone and $H\overset{O}{\overset{\|}{C}}{-}CH_2{-}\overset{O}{\overset{\|}{C}}{-}H$

(d) none of these

66. The product of the following reaction

$$CH_3CH_2\overset{O}{\overset{\|}{C}}{-}OH + CH_3^{18}OH \xrightarrow{H^+}$$

is

(a) $CH_3CH_2\overset{O}{\overset{\|}{C}}{-}^{18}OCH_3$

(b) $CH_3CH_2\overset{^{18}O}{\overset{\|}{C}}{-}^{18}OCH_3$

(c) $CH_3CH_2\overset{^{18}O}{\overset{\|}{C}}{-}OCH_3$

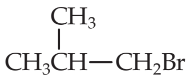
(d) $CH_3CH_2\overset{O}{\overset{\|}{C}}{-}OCH_3$

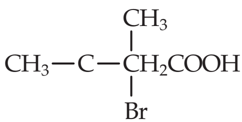
67. The final product (VI) obtained in the sequence of reactions

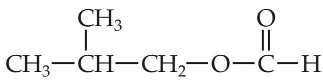
$$CH_3\overset{CH_3}{\overset{|}{C}}HCOOH \xrightarrow{LiAlH_4} \text{I} \xrightarrow{H_2O} \text{II} \xrightarrow{PBr_3} \text{III}$$

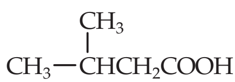
$$\xrightarrow[\text{Ether}]{\text{Mg}} \text{IV} \xrightarrow{CO_2} \text{V} \xrightarrow[H_2O]{H^+} \text{VI}$$

is

(a) 

(b) 

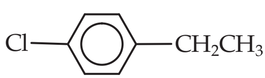
(c) 

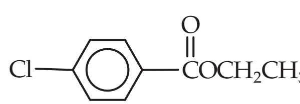
(d) 

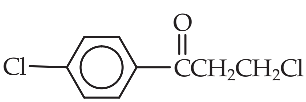
68. The final product (III) obtained in the sequence of reactions

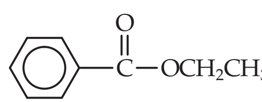
$p\text{-chlorotoluene} \xrightarrow[\text{2. } H^+]{\text{1. } KMnO_4,\ OH^-} \text{I} \xrightarrow{SOCl_2} \text{II} \xrightarrow{CH_3CH_2OH} \text{III}$

is

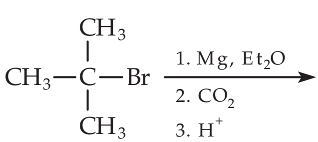
(a) 

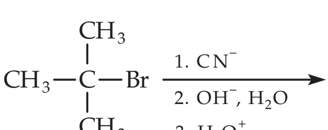
(b) 

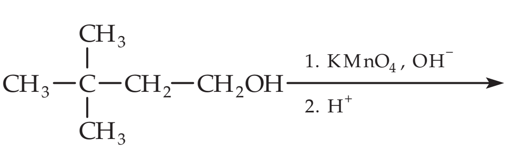
(c) 

(d) 

69. Which of the following cannot be used for the synthesis of 2,2-dimethylpropionic acid?

(a) 

(b) 

(c) 

(d) $$CH_3-\overset{\displaystyle CH_3}{\underset{\displaystyle CH_3}{\overset{|}{\underset{|}{C}}}}-CHO \xrightarrow[2.\ H^+]{1.\ KMnO_4\ ,\ OH^-}$$

70. The major product (III) obtained in the sequence of reactions

$$CH_3-\overset{\displaystyle CH_3}{\overset{|}{C}H}-CH_2CH_2COOH \xrightarrow[P]{1\ \text{mole}\ Cl_2} \text{I} \xrightarrow{SOCl_2} \text{II} \xrightarrow{CH_3OH} \text{III}$$

is

(a) $(CH_3)_2CHCH_2\overset{\displaystyle Cl}{\overset{|}{C}H}-COOCH_3$

(b) $(CH_3)_2CH\overset{\displaystyle OCH_3}{\overset{|}{C}}HCH_2COCl$

(c) $(CH_3)_2CHCH_2\overset{\displaystyle OCH_3}{\overset{|}{C}}HCHCOCl$

(d) $(CH_3)_2\overset{\displaystyle Cl}{\overset{|}{C}}CH_2CH_2COOCH_3$

71. Which of the following is an example of a Hunsdieker reaction?

(a) $CH_2(CO_2H)_2 \xrightarrow{\Delta} CH_3CO_2H$

(b) $CH_3\underset{\displaystyle O}{\underset{\|}{C}}CH_2CO_2H \xrightarrow{\Delta} CH_3\underset{\displaystyle O}{\underset{\|}{C}}CH_3$

(c) $CH_3-\underset{\displaystyle O}{\underset{\|}{C}}-CH_3 \xrightarrow[Br_2]{KOH} CH_3CO_2^-K^+ + CHBr_3$

(d) $CH_3CH_2COOH \xrightarrow[2.\ Br_2,\ CCl_4]{1.\ Ag_2O} CH_3CH_2Br$

72. In nucleophilic substitutions, the relative reactivity of acyl compounds is

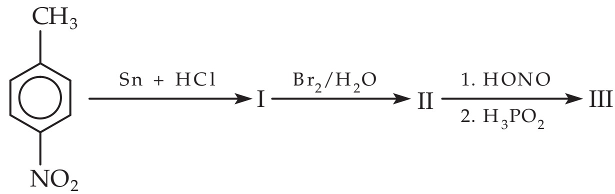
(a) acyl chloride > ester > acid anhydride > amide

(b) acid anhydride > acyl chloride > ester > amide

(c) acyl chloride > acid anhydride > ester > amide

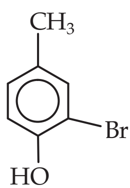
(d) ester > acyl chloride > acid anhydride > amide

73. The final product III obtained in the reaction

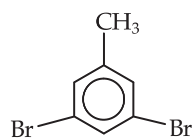


is

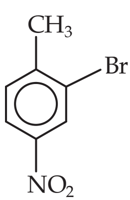
(a)



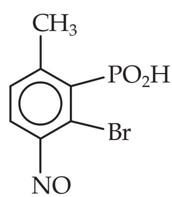
(b)



(c)



(d)



74. What will be the major product in the reaction

$$CH_3CH_2\overset{\overset{\displaystyle O}{\|}}{C}OC_2H_5 \xrightarrow[2.\ H^+]{1.\ NaOEt}$$

(a) $CH_3CH_2COCH_2CH_2CO_2C_2H_5$

(b) $CH_3CH_2CO_2CH_2CH_2CO_2C_2H_5$

(c) $CH_3CH_2CO\underset{\underset{\displaystyle CH_3}{|}}{C}HCO_2C_2H_5$

(d) $CH_3CH_2\underset{\underset{\displaystyle OH}{|}}{C}H-\underset{\underset{\displaystyle CH_3}{|}}{C}HCO_2C_2H_5$

75. The hybridization state of a carbocation is

(a) sp^4 (b) sp^3

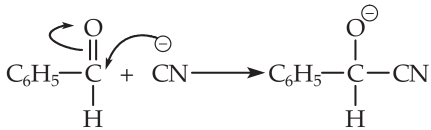
(c) sp^2 (d) sp

76. How many electrons are present in the p orbital of a methyl cation (CH_3^+)?

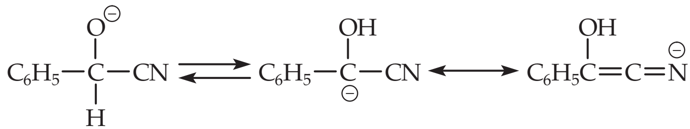
(a) Two (b) Three (c) Four (d) None

77. The reaction of benzaldehyde with HCN to give benzoin takes place in the following steps.

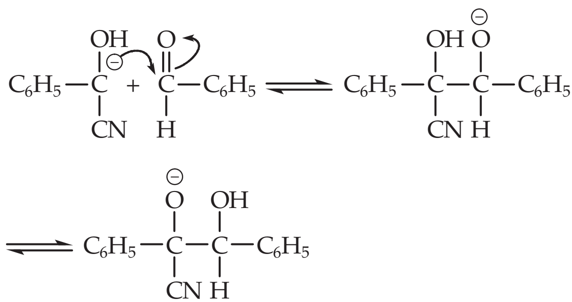
(a)



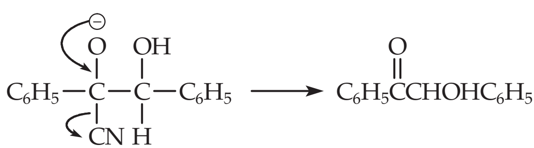
(b)



(c)



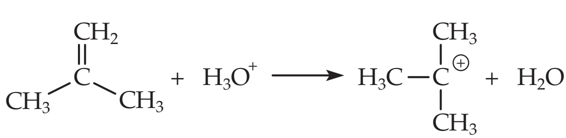
(d)



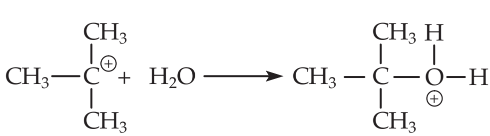
Which of these is the rate-determining step?

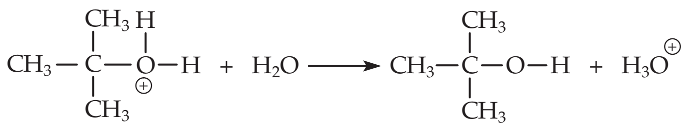
78. In the acid-catalysed hydration of an alkene, the rate-determining step is

(a)



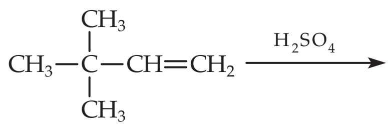
(b)



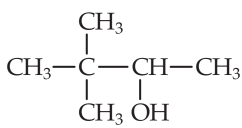
(c) 

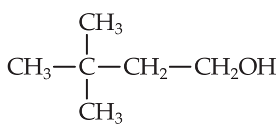
(d) none of these

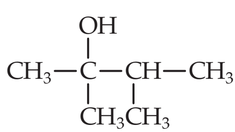
79. The major product obtained in the reaction



is

(a) 

(b) 

(c) 

(d) a mixture of (a) and (b) in equal proportions

80. What is the order of reactivity of the alkenes $(CH_3)_2C{=}CH_2$(I), $CH_3CH{=}CH_2$(II) and $CH_2{=}CH_2$(III) when subjected to acid-catalysed hydration?

(a) I > II > III (b) I > III > II

(c) III > II > I (d) II > I > III

• *Type 2* •

Choose the correct options. More than one option is correct.

81. Which of the following groups are *o*- and *p*-directing?

(a) $-NH_2$ (b) $-NHCOCH_3$

(c) $-CN$ (d) $-SO_3H$

82. Which of the following groups are *m*-directing?

(a) —CHO (b) —OH
(c) —$OCOCH_3$ (d) —COOH

83. Which of the following are nucleophiles?

(a) Water (b) Ammonia
(c) Triphenylsulphide (d) Iodides

84. Which of the following are electrophiles?

(a) Dimethyl sulphide (b) Bromides
(c) Carbon dioxide (d) Ammonia

85. Which of the following arrangements show a correct order of nucleophilicity?

(a) $I^- > Br^- > Cl^- > F^-$ (b) $RS^- > RO^-$
(c) $R_3N: > R_3P:$ (d) $RO^- > RS^-$

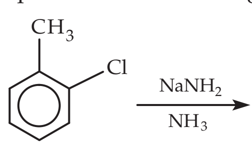
86. Which of the following are electrophiles?

(a) BF_3 (b) $Cl_2C:$ (c) NR_4^+ (d) I^-

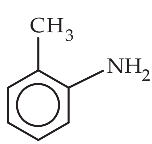
87. Which of the following are aprotic solvents?

(a) DMSO (b) DMF (c) H_2O (d) CH_3COOH

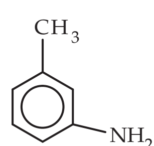
88. What is the product expected in the following reaction?



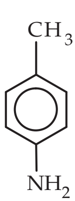
(a)



(b)



(c)



(d) none of these

89. Which of the following statements are correct for butadiene

$$\overset{4}{C}H_2{=}\overset{3}{C}H{-}\overset{2}{C}H{=}\overset{1}{C}H_2$$

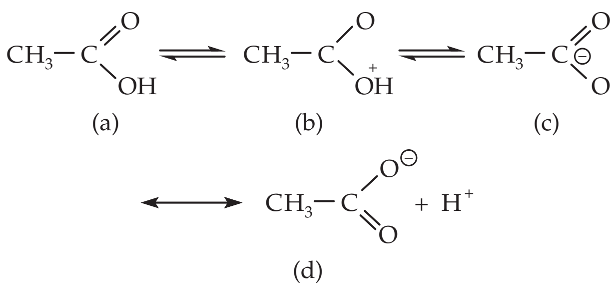
(a) The $C_1–C_2$ and $C_3–C_4$ bonds are longer than a carbon-carbon double bond.

(b) The C_1–C_2 and C_3–C_4 bonds are shorter than a carbon-carbon double bond.

(c) The C_2–C_3 bond is slightly shorter than a carbon-carbon single bond.

(d) The C_2–C_3 bond is slightly longer than a carbon-carbon double bond.

90. Which of the following structures have resonance stability?



91. Which of the following groups have a +M effect (an electron-attracting mesomeric effect)?

(a) $-\ddot{N}H_2$ (b) $-\ddot{\underset{\cdot\cdot}{S}}R$

(c) $-NO_2$ (d) $-CHO$

92. Which of the following groups have a –M effect (an electron-repelling mesomeric effect)?

(a) $-\ddot{\underset{\cdot\cdot}{O}}H$ (b) $-\ddot{\underset{\cdot\cdot}{Cl}}\!:$

(c) $>C=O$ (d) $-SO_3H$

93. Br has a low reactivity in $CH_2{=}CH{-}Br$ because

(a) the C–Br bond has a partial double-bond character

(b) of the +M effect of bromine

(c) Br is electronegative

(d) of none of these

94. Which of the following statements are correct?

(a) Under normal conditions, 2,6-dimethylbenzoic acid cannot be esterified with ethyl alcohol and concentrated sulphuric acid.

(b) 2,6-Dimethylphenylacetic acid can be esterified with ethyl alcohol and concentrated sulphuric acid.

(c) The nitration of tertiary butyl benzene gives a *p*-nitro product.

(d) 2,6-Dimethyl-N,N-dimethylaniline does not undergo azo coupling.

95. Which of the following statements are correct?

(a) The nucleophilic addition of HCN to $CH_3CH{=}CHCHO$ results in a major addition to C=C.

(b) The nucleophilic addition of HCN to $CH_3CH{=}CHCHO$ results in a major addition to C=O.

(c) The nucleophilic addition of PhMgBr to PhCH=CH–CHO results in addition to C=O.

(d) The nucleophilic addition of PhMgBr to $PhCH{=}CH{-}COCMe_3$ results in addition to C=C.

96. On treatment with strong NaOH at 340°C, *p*-chlorotoluene gives

(a) *o*-cresol (b) *m*-cresol

(c) *p*-cresol (d) none of these

97. Under S_N1 conditions, the hydrolysis of neopentyl bromide,

$$\begin{array}{c} CH_3 \\ | \\ CH_3{-}C{-}CH_2Br, \\ | \\ CH_3 \end{array}$$

gives

(a) $\begin{array}{c} CH_3 \\ | \\ CH_3{-}C{-}CH_2CH_3 \\ | \\ CH_3 \end{array}$ (b) $\begin{array}{c} CH_3 \\ | \\ CH_3{-}C{-}CH_2OH \\ | \\ CH_3 \end{array}$

(c) $\begin{array}{l} CH_3{-}C{=}CH{-}CH_3 \\ \quad\;\; | \\ \quad\; CH_3 \end{array}$ (d) none of these

98. Which of the following statements are correct?

(a) The addition of HBr to propene gives 2-bromopropane.

(b) The addition of HBr to propene gives 1-bromopropane.

(c) The addition of HCl to vinyl chloride gives ethylidene chloride.

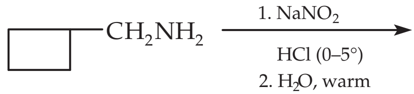
(d) The addition of HCl to vinyl chloride gives ethylene chloride.

99. The addition of bromine to butadiene gives

(a) $CH_2Br{-}CHBr{-}CH{=}CH_2$ (b) $CH_2Br{-}CH{=}CH{-}CH_2Br$

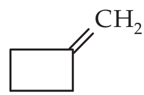
(c) $CH_3{-}CHBr{-}CHBr{-}CH_3$ (d) $CH_3{-}CH_2CH_2CHBr_2$

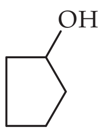
100. In the reaction



the product obtained is

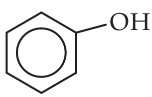
(a) 

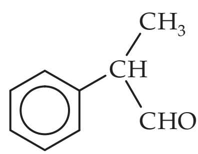
(b) 

(c) 

(d) 

101. The oxidation in air of cumene (isopropyl benzene) followed by hydrolysis yields

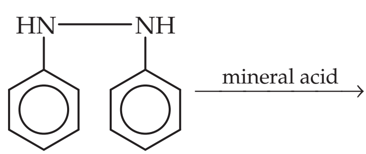
(a) 

(b) 

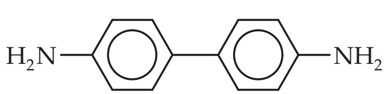
(c) $CH_3-\overset{\overset{\displaystyle O}{\|}}{C}-CH_3$

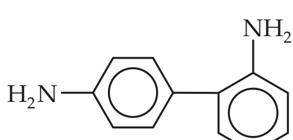
(d) none of these

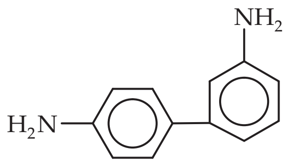
102. The reaction



gives

(a) 

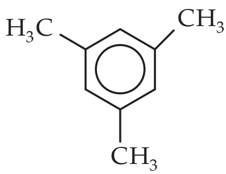
(b) 

(c) 

(d) none of these

103. The reaction of acetone with dry HCl gas gives

(a) $(CH_3)_2C{=}CHCOCH_3$

(b) 

(c) $(CH_3)_2C{=}CH{-}COCH{=}C(CH_3)_2$

(d) none of these

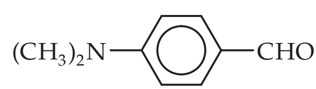
104. The Cannizzaro reaction of benzaldehyde and formaldehyde in the presence of NaOH gives

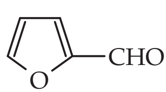
(a) $C_6H_5CH_2OH$ (b) C_6H_5COONa

(c) HCOONa (d) CH_3OH

105. Which of the following will undergo a Cannizzaro reaction?

(a) $(CH_3)_2CHCHO$

(b) 

(c) 

(d) OHC—COOH

106. In the reaction

$$CH_3CH{=}CH_2 \xrightarrow[\text{benzoyl peroxide}]{HX} \underset{(A)}{CH_3CH_2CH_2X}$$

the anti-Markovnikov product (A) cannot be obtained by using

(a) HBr (b) HCl (c) HI (d) none of these

107. In the reaction

$$C_6H_5\overset{\overset{\large O}{\|}}{C}-\overset{\overset{\large O}{\|}}{C}-H \xrightarrow{NaOH}$$

which of the following are not obtained?

(a) $C_6H_5-\overset{\overset{\displaystyle O}{\|}}{C}-COONa$

(b) $C_6H_5-\overset{\overset{\displaystyle O}{\|}}{C}-CH_2OH$

(c) $C_6H_5-\underset{\underset{\displaystyle OH}{|}}{CH}-COONa$

(d) $C_6H_5-\overset{\overset{\displaystyle O}{\|}}{C}-\overset{\overset{\displaystyle O}{\|}}{C}-C_6H_5$

108. The reaction

$$R-\overset{\overset{\displaystyle O}{\|}}{C}-NH_2 \xrightarrow{NaOBr(Br_2 + NaOH)} RNH_2$$

has the intermediates

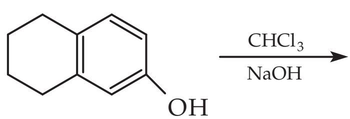
(a) $R-\overset{\overset{\displaystyle O}{\|}}{C}-NHBr$

(b) $R-\overset{\overset{\displaystyle O}{\|}}{C}-\ddot{N}:$

(c) $R-N=C=O$

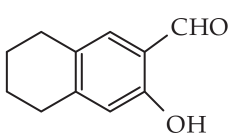
(d) $R-NH-\underset{\underset{\displaystyle OH}{|}}{C}=O$

109. The products obtained in the reaction

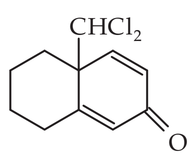


are

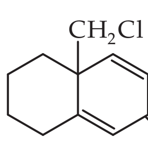
(a)



(b)



(c)



(d) none of these

110. Which of the following is an example of nucleophilic addition to acetone?

(a) Ketal formation

(b) Reduction with hydrogen gas

(c) Cyanohydrin formation

(d) Bisulphite addition

111. Which of the following species bear a positive charge?

(a)
$$\begin{array}{ccc} & H & \\ & \cdot\cdot & \\ H: & B & :H \\ & \cdot\cdot & \\ & H & \end{array}$$

(b)
$$\begin{array}{ccc} & H & \\ & \cdot\cdot & \\ H: & N & : \\ & \cdot\cdot & \\ & H & \end{array}$$

(c)
$$\begin{array}{ccc} & H & \\ & \cdot\cdot & \\ H: & N & :H \\ & \cdot\cdot & \\ & H & \end{array}$$

(d)
$$\begin{array}{ccc} & H & \\ & \cdot\cdot & \\ H: & O & :H \\ & \cdot\cdot & \end{array}$$

112. Which of the following has a trigonal planar (or triangular) structure

(a) $:\overset{-}{C}H_3$ (b) $\overset{+}{C}H_3$ (c) BF_3 (d) $:\overset{+}{O}H_3$

113. Which of the following statements are true for the S_N1 reactions of alkyl halides?

(a) The rate of an S_N1 reaction depends on the concentration of the alkyl halide.

(b) The S_N1 reations of alkyl halides are favoured by polar solvents.

(c) The rate of an S_N1 reaction depends on the concentration of the nucleophile.

(d) The rate of an S_N1 reaction depends on the concentration of the substrate as well as that of the nucleophile.

114. In which of the following reactions is there a possibility of rearrangement?

(a) S_N1 reactions (b) S_N2 reactions

(c) E1 reactions (d) E2 reactions

115. Which of the following are examples of electrophilic addition?

(a)
$$CH_3CH{=}CH_3 + H_2O \longrightarrow CH_3-\overset{\overset{\displaystyle OH}{|}}{C}H-CH_3$$

(b)
$$CH_3CH{=}CH_3 + HBr \xrightarrow{\text{Peroxides}} CH_3\underset{\underset{\displaystyle Br}{|}}{C}HCH_3$$

(c)
$$CH_3CH{=}CHCH_3 + Cl_2 \longrightarrow CH_3\underset{\underset{\displaystyle Cl}{|}}{C}H-\underset{\underset{\displaystyle Cl}{|}}{C}H-CH_3$$

(d) None of these

116. Which of the following statements are true for the organoborane

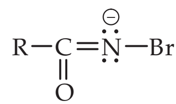
$$CH_3\,CH_2\underset{\underset{\displaystyle \diagup B \diagdown}{|}}{C}H-CH_2CH_3\ ?$$

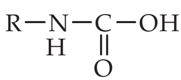
(a) It can be thermally rearranged.
(b) It can be oxidized to 3-pentanol.
(c) It can be converted to pentane.
(d) None of these

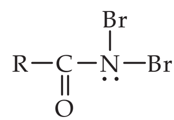
117. Which of the following are intermediates in the Hofmann degradation reaction?R—N=C=O

$$RCONH_2 \xrightarrow[Br]{KOH} RNH_2$$

(a) $R-N=C=O$

(b) 

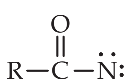
(c) 

(d) 

118. The intermediates involved in the Curtius reaction

$$RCON_3 \longrightarrow RNH_2$$

are

(a) 

(b) $R-\ddot{N}=C=O$

(c) $R-C\equiv N$

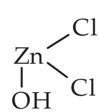
(d) none of these

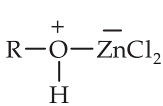
119. In the reaction

$$ROH + HCl \xrightarrow{ZnCl_2} RCl + H_2O$$

the intermediates are

(a) R^+

(b) 

(c) 

(d) none of these

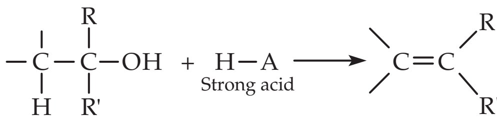
120. Which of the following statements are correct?

(a) RO^- is a stronger nucleophile than OH^-.
(b) RCO_2^- is a stronger nucleophile than OH^-.
(c) RCO_2^- is a stronger nucleophile than ROH.
(d) RO^- is a weaker nucleophile than OH^-.

121. Which of the following are polar aprotic solvents?

(a) Dimethylsulfoxide
(b) Hexamethylphosphoramide
(c) Acetone
(d) N,N-Dimethylformamide

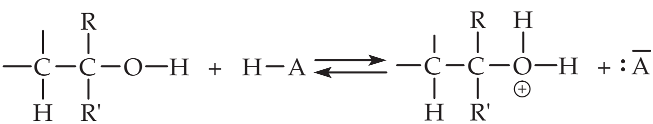
122. In the reaction



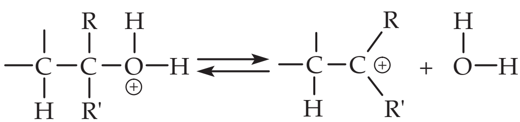
2° or 3° alcohol

which of the following steps are not rate-determining?

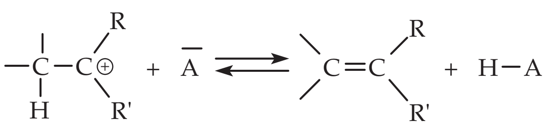
(a)



(b)

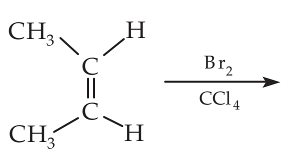


(c)



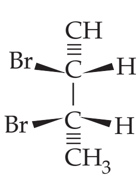
(d) None of these

123. In the reaction

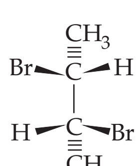


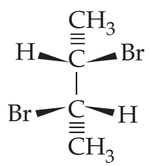
the products obtained are

(a)



(b)



(c) 

(d) none of these

Answers

1. a	**2.** b	**3.** d	**4.** a	**5.** c
6. a	**7.** d	**8.** a	**9.** c	**10.** a
11. c	**12.** d	**13.** a	**14.** c	**15.** a
16. b	**17.** b	**18.** b	**19.** c	**20.** d
21. b	**22.** c	**23.** a	**24.** b	**25.** a
26. c	**27.** c	**28.** a	**29.** b	**30.** b
31. b	**32.** a	**33.** c	**34.** d	**35.** a
36. a	**37.** c	**38.** c	**39.** a	**40.** b
41. d	**42.** c	**43.** b	**44.** b	**45.** c
46. b	**47.** a	**48.** d	**49.** a	**50.** a
51. b	**52.** c	**53.** d	**54.** d	**55.** c
56. a	**57.** a	**58.** a	**59.** d	**60.** d
61. a	**62.** c	**63.** c	**64.** b	**65.** a
66. a	**67.** d	**68.** b	**69.** c	**70.** a
71. d	**72.** c	**73.** b	**74.** c	**75.** c
76. d	**77.** c	**78.** a	**79.** c	**80.** a
81. a, b	**82.** a, d	**83.** a, b, c, d	**84.** a, c	**85.** a, b
86. a, b, c	**87.** a, b	**88.** a, b	**89.** a, c	**90.** c, d
91. a, b	**92.** c, d	**93.** a, b	**94.** a, b, c, d	**95.** a, c, d
96. b, c	**97.** a, c	**98.** a, c	**99.** a, b	**100.** a, b, c, d
101. a, c	**102.** a, b	**103.** a, c	**104.** a, c	**105.** a, c, d
106. b, c	**107.** a, b, d	**108.** a, b, c, d	**109.** a, b	**110.** a, c, d
111. c, d	**112.** b, c	**113.** a, b	**114.** a, c	**115.** a, b, c
116. a, b, c	**117.** a, b, c	**118.** a, b	**119.** a, b, c	**120.** a, c
121. a, b, d	**122.** a, c	**123.** b, c		

Hints to More Difficult Problems

16. Hyperconjugation satisfactorily explains the preferential formation of the product (b).

17. The formation of the product (b) is due to the conjugation of the double bond with the carbonyl group, which gives resonance stability.

22. The formation of the abnormal product (a) is due to the rearrangement of the secondary carbocation to the tertiary carbocation for stability.

29. The unusual product (b) is obtained contrary to the Saytzev rule due to steric hindrance.

32. This is a case of pinacol-pinacolone rearrangement.

33. This is case of the rearrangement of the alicyclic ring system (Demjanov rearrangement).

35. This is a case of Claisen rearrangement.

36. End-interchange occurs twice during para migration, and so there is no rearrangement in the final product.

44. Product (b) is obtained due to the strong electron-withdrawing effect of the CN group, rendering the secondary carbocation less stable than the primary carbocation. Also, the carbocation is separated from CN by two carbon atoms, and the destabilization by the inductive effect is less.

89. Consider the following resonance structure

$$\underset{(1)}{CH_2{=}CH{-}CH{=}CH_2} \longleftrightarrow \underset{(2)}{\overset{\ominus}{C}H_2{-}\overset{\oplus}{C}H{-}CH{=}CH_2}$$

$$\longleftrightarrow \underset{(3)}{CH_2{=}CH{-}\overset{\oplus}{C}H{-}\overset{\ominus}{C}H_2} \longleftrightarrow \underset{(4)}{\overset{\ominus}{C}H_2{-}CH{=}CH{-}\overset{\oplus}{C}H_2}$$

$$\longleftrightarrow \underset{(5)}{\overset{\oplus}{C}H_2{-}CH{=}CH{-}\overset{\ominus}{C}H_2}$$

The structures (2) and (3) show the partial single-bond character of the C_1–C_2 and C_3–C_4 bonds, and (4) and (5) the partial double-bond character of the C_2–C_3 bond. This explains the observed anomalies in the bond distances.

90. Charge separation structures are less important than those in which the charge is delocalized, because there is electrostatic attraction between unlike charges.

93. The low reactivity of a halogen bonded to an unsaturated carbon is due to the +M effect of the halogen. The C–Br bond in vinyl chloride has a partial double-bond character due to the +M effect of bromine, resulting in low reactivity.

94. The steric effect plays a role in all these reactions.

95. The formation of the products in (a) can be explained by the fact that C=O is a stronger bond than C=C, and so the preferential addition is to

C=C. In the formation of the product in (c), steric hindrance is a major factor. However, in case of (d), the inductive effect of the Me group is a major factor, in addition to steric hindrance.

97. The formation of the unexpected product (a) is due to the rearrangement of the first formed $\overset{\circ}{1}$ carbocation to the $\overset{\circ}{3}$ carbocation. This also explains the formation of the product (c).

107. The product (c) is obtained due to an intramolecular Cannizzaro reaction.

❑

3

Hydrocarbons

• *Type 1* •

Choose the correct option. Only one option is correct.

1. Using which of the following reagents can one perform a simple test that can be used to differentiate between $C_6H_5C{\equiv}CH$ and $C_6H_5CH{=}CH_2$?

(a) $NaOH/H_2O$ (b) Br_2/CCl_4
(c) $Ag(NH_3)_2OH$ (d) CrO_3/H_2SO_4

2. The addition of HCl to 1-phenylpropene gives

(a) $C_6H_5CHClCH_2CH_3$ (b) $C_6H_5CH_2CHClCH_3$
(c) $C_6H_5CH_2CH_2CH_2Cl$ (d) $C_6H_5CH(CH_3)CH_2Cl$

3. The addition of HBr in the presence of a peroxide to 1-phenylpropene gives

(a) $C_6H_5CHBrCH_2CH_3$ (b) $C_6H_5CH_2CHBrCH_3$
(c) $C_6H_5CH(CH_3)CH_2Br$ (d) $C_6H_5CH_2CH_2CH_2Br$

4. By using which of the following can the conversion

$$PhC{\equiv}CH \longrightarrow PhC{\equiv}CCH_3$$

be achieved?

(a) Br_2/CCl_4, then KOH (b) Na, then CH_3CH_2I
(c) Na, then CH_3I (d) CH_2N_2

5. Which conformation of ethane has the lowest potential energy?

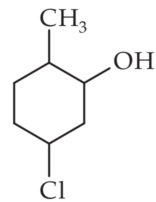
(a) Eclipsed (b) Skewed
(c) Staggered (d) All will have equal PE

6. The relative energies of the ethane conformations are in the order

(a) skewed < eclipsed < staggered
(b) staggered < eclipsed < skewed

(c) skewed < staggered < eclipsed
(d) staggered < skewed < eclipsed

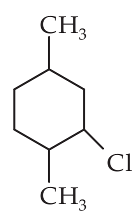
7. The name of the compound



is

(a) 2-methyl-5-chlorocyclohexanol
(b) 3-chloro-6-methylcyclohexanol
(c) 2-hydroxy-4-chlorocyclohexane
(d) 3-hydroxy-4-methylchlorocyclohexane

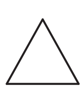
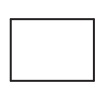
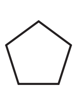
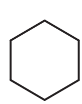
8. The name of the compound



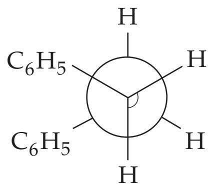
is

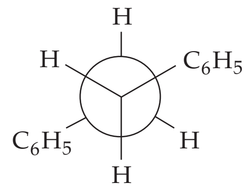
(a) 2,5-dimethylchlorocyclohexane
(b) 3,6-dimethylchlorocyclohexane
(c) 3-chloro-1,4-xylene
(d) none of these

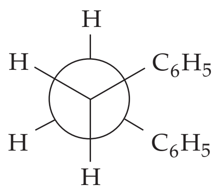
9. Which cycloalkane has the lowest heat of combustion per CH_2 group?

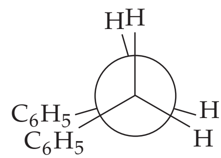
(a) 
(b) 
(c) 
(d) 

10. The most stable conformation of 1,2-diphenylethane is

(a)


(b)


(c)


(d)


11. The reaction of RCH_2CHX_2 with alcoholic KOH followed by treatment with $NaNH_2$ gives

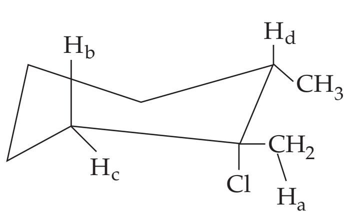
(a) only RCH=CHX (b) only RC≡CH
(c) a mixture of (a) and (b) (d) none of these

12. A compound C_6H_{10} decolourizes bromine in carbon tetrachloride and reacts with Ag^+ in ammonia to give an insoluble salt. On treatment with excess hydrogen in the presence of an Ni catalyst, this compound gives 2-methylpentane. The structure of the compound C_6H_{10} is

(a) $CH_3\underset{\underset{CH_3}{|}}{C}=CH-CH=CH_2$ (b) $CH_2=\underset{\underset{CH_3}{|}}{C}-CH=CHCH_3$

(c) $CH_3\underset{\underset{CH_3}{|}}{C}HC\equiv CCH_3$ (d) $CH_3-\overset{\overset{H}{|}}{\underset{\underset{CH_3}{|}}{C}}-CH_2C\equiv CH$

13. In the following halogen-substituted hydrocarbon, the hydrogen atom that can be eliminated most readily is



(I)

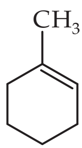
(a) H_a (b) H_b (c) H_c (d) H_d

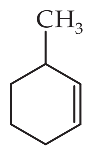
14. On catalytic hydrogenation, an organic compound $X(C_7H_{12})$ absorbs 1 mol of hydrogen and yields a compound C_7H_{14}. On ozonolysis and subsequent treatment with Zn/H_2O, the compound

$$CH_3\overset{\overset{\displaystyle O}{\|}}{C}-CH_2-CH_2-CH_2-CH_2-\overset{\overset{\displaystyle O}{\|}}{C}H$$

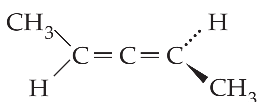
is obtained. The structure of X is

(a) $CH_3-\underset{\underset{\displaystyle CH_2}{\|}}{C}-CH_2CH_2CH{=}CH_2$ (b) $CH_3\underset{\underset{\displaystyle CH_3}{|}}{C}HC{\equiv}CCH_2CH_3$

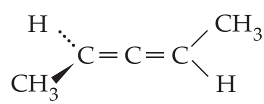
(c) 

(d) 

15. The molecules



and



are

(a) enantiomers (b) diastereomers

(c) structural isomers (d) none of these

16. Which of the following statements is true for ethane, ethene and acetylene?

(a) Acetylene is the weakest acid and has the longest C—H bond distance.

(b) Acetylene is the strongest acid and has the shortest C—H bond distance.

(c) Ethane is the strongest acid and has the longest C—H bond distance.

(d) Ethene is the strongest acid and has the shortest C—H bond distance.

17. On oxidation with hot aqueous $KMnO_4$, a compound X gives 2-methylpropionic acid and propionic acid. Which of the following is the structure of X?

(a) $HOOC\underset{\underset{\displaystyle CH_3}{|}}{C}-CH_2-CH_2-CH_2COOH$

(b) $CH_3\underset{\underset{\displaystyle CH_3}{|}}{C}HCH_2C{\equiv}CCH_3$

(c) $CH_3\underset{\underset{\displaystyle CH_3}{|}}{C}HC{\equiv}CCH_2CH_3$

(d) $CH_3\underset{\underset{\displaystyle CH_3}{|}}{C}HCH{=}CHCH_2CH_3$

18. On catalytic hydrogenation, a compound X (C_7H_{12}) absorbs 2 mol of hydrogen and yields 2-methylhexane. On treatment with $Ag(NH_3)_2OH$, X gives a precipitate which contains silver and which regenerates X on treatment with dilute HNO_3. The structure of X is

(a) $CH_3CH_2CH_2CH_2CH_2C{\equiv}CH$ (b) $CH_3C{\equiv}CCH_2\underset{\underset{\displaystyle CH_3}{|}}{C}H{-}CH_3$

(c) $CH_2{=}CHCH{=}CH\underset{\underset{\displaystyle CH_3}{|}}{C}HCH_3$ (d) $CH_3{-}\underset{\underset{\displaystyle CH_3}{|}}{C}HCH_2CH_2C{\equiv}CH$

19. Among the following dienes, which is the most stable?

(a) $CH_3CH{=}CHCH_2CH{=}CH_2$ (b) $CH_3CH{=}CHCH{=}CHCH_3$

(c) $CH_2{=}CHCH_2CH_2CH{=}CH_2$ (d) $CH_2{=}CH\underset{\underset{\displaystyle CH_3}{|}}{C}HCH{=}CH$

20. The main product obtained in the reaction of 2-butene with N-bromosuccinimide is

(a) $CH_2BrCHBrCH_2CH_3$ (b) $CH_3CHBrCH_2CH_3$

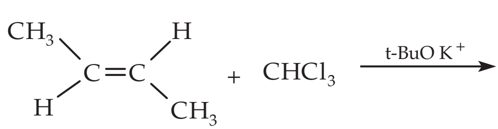
(c) $CH_3CH{=}CBrCH_3$ (d) $CH_3CH{=}CHCH_2Br$

21. Among the following, which has the shortest carbon-carbon single bond?

(a) $CH_3{-}CH_3$ (b) $CH_2{=}CH{-}CH_3$

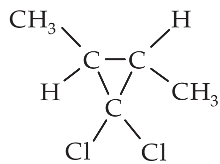
(c) $HC{\equiv}C{-}C{\equiv}CH$ (d) $CH_2{=}CH{-}C{\equiv}CH$

22. The product obtained in the reaction



is

(a) $CH_3CH_2\underset{\underset{\displaystyle CCl_3}{|}}{C}HCH_3$ (b) $CH_3\underset{\underset{\displaystyle Cl}{|}}{C}H{-}\underset{\underset{\displaystyle CHCl_2}{|}}{C}HCH_3$

(c) 

(d) none of these

23. Which is the most stable conformation of cyclohexane?

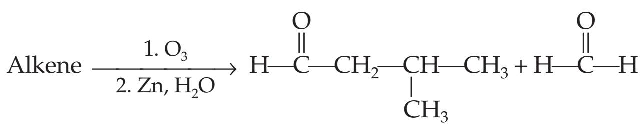
(a) Chair (b) Twist (c) Boat (d) Staggered

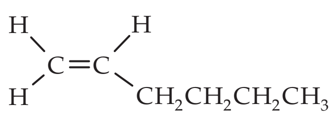
24. Which of the following reagents can be used in a simple chemical test to distinguish $CH_2BrCH{=}CH_2$ from $CH_3CH{=}CHBr$?

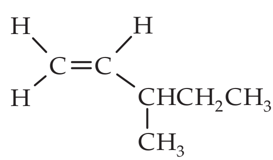
(a) $Ag(NH_3)_2OH$ (b) Br_2/CCl_4

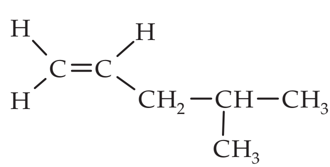
(c) Cold $KMnO_4$ (d) $AgNO_3/C_2H_5OH$

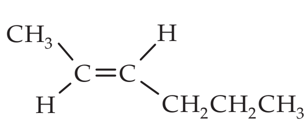
25. Which alkene will undergo the following reaction?



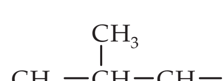
(a) 

(b) 

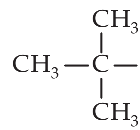
(c) 

(d) 

26. The secondary butyl group is represented as

(a) $CH_3CH_2CH_2CH_2—$ (b) 

(c) 

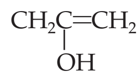
(d) 

27. The product obtained in the reaction

$$H_3C{-}C{\equiv}CH \xrightarrow[150°C,\ 6\ hr]{alc.\ KOH}$$

is

(a) $CH_3CH{=}CHOH$

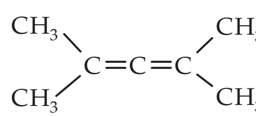
(b) 

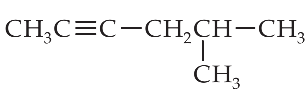
(c) $CH_2{=}C{=}CH_2$

(d) none of these

28. On ozonolysis, a compound C_7H_{12} gives acetone and carbon dioxide. The structure of the compound can be

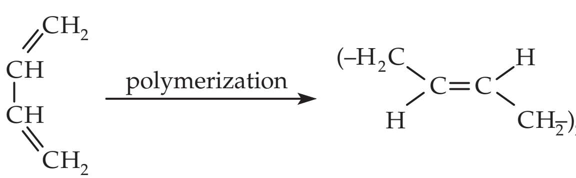
(a) $CH_3CH_2C{\equiv}C{-}CH_2CH_2CH_3$

(b) 

(c) 

(d) none of these

29. The polymerization of butadiene according to the reaction



is an example of

(a) 1,2 addition

(b) *cis*-1,4 addition

(c) *trans*-1,4 addition

(d) none of these

30. The reaction of ethyne with bromine water gives

(a) *cis*-1,2-dibromoethene

(b) *trans*-1,2-dibromoethene

(c) 1,1,2,2-tetrabromoethane

(d) none of these

31. The order of the bond strength of C—H bonds involving sp-, sp^2- and sp^3-hybridized carbon atoms is

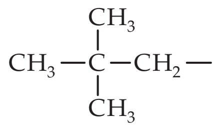
(a) $sp > sp^2 > sp^3$

(b) $sp^3 > sp^2 > sp$

(c) $sp^2 > sp^3 > sp$

(d) $sp^2 > sp > sp^3$

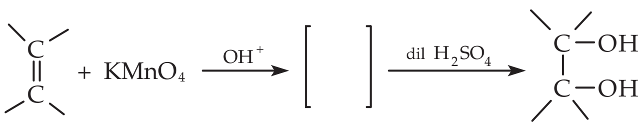
32. The group



is called the

(a) butyl group
(b) secondary butyl group
(c) tertiary butyl group
(d) neopentyl group

33. In the oxidation of alkenes with a dilute $KMnO_4$ solution followed by acidification with dilute H_2SO_4 to give diol,



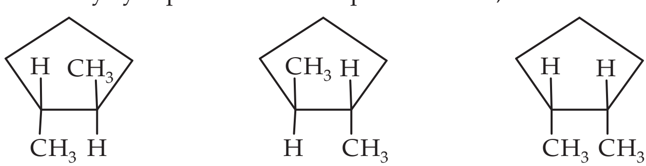
the OH groups come from

(a) NaOH
(b) H_2O
(c) $KMnO_4$
(d) H_2SO_4

34. Which of the following hydrocarbons cannot be oxidized by $KMnO_4$/alkali?

(a) Toluene
(b) Ethylbenzene
(c) Isopropylbenzene
(d) Tertiary butylbenzene

35. 1,2-Dimethylcyclopentane can be represented as I, II and III.



I II III

Which of these structures are enantiomers?

(a) I and II
(b) I and III
(c) II and III
(d) I, II and III

36. The final product obtained in the reaction

$$CH_3CH_2CH{=}CH_2 \xrightarrow[2\cdot NaNH_2,\ 110\text{–}160°C]{1\cdot Br_2/CCl_4}$$

is

(a) $CH_3CH_2CH{=}CHBr$
(b) $CH_3CH_2\underset{\mid \atop Br}{C}{=}CH_2$
(c) $CH_3CH_2C{\equiv}CH$
(d) none of these

37. The basicities of $CH_3CH_2:^-$, $CH_2{=}CH:^-$ and $HC{\equiv}C:^-$ are of the order

(a) $CH_3CH_2:^- > CH_2{=}CH:^- > HC{\equiv}C:^-$
(b) $HC{\equiv}C:^- > CH_2{=}CH:^- > CH_3CH_2:^-$
(c) $CH_2{=}CH:^- > CH_3CH_2:^- > HC{\equiv}C:^-$
(d) All the three are equally basic.

38. The acidities of H_2O, CH_3OH, $CH_3{-}C{\equiv}CH$, NH_3, $CH_2{=}CH_2$ and CH_3CH_3 are of the order

(a) $H_2O > CH_3OH > CH_3C{\equiv}CH > NH_3 > CH_2{=}CH_2 > CH_3{-}CH_3$
(b) $CH_3OH > H_2O > NH_3 > CH_3C{\equiv}CH > CH_3{-}CH_3 > CH_2{=}CH_2$
(c) $CH_3{-}CH_3 > CH_2{=}CH_2 > NH_3 > CH_3C{\equiv}CH > CH_3OH > H_2O$
(d) $NH_3 > CH_3C{\equiv}CH > CH_3{-}CH_3 > CH_2{=}CH_2 > CH_3OH > H_2O$

39. The reduction of 4-octyne with H_2 in the presence of Pd/$CaCO_3$-quinoline gives

(a) *trans*-4-octene
(b) *cis*-4-octene
(c) a mixture of *cis*- and *trans*-4-octene
(d) a completely reduced product C_8H_{18}

40. On halogenation, an alkane (C_5H_{12}) gives only one monohalogenated product. The alkane is

(a) *n*-pentane (b) 2-methylbutane
(c) 2,2-dimethylpropane (d) cyclopentane

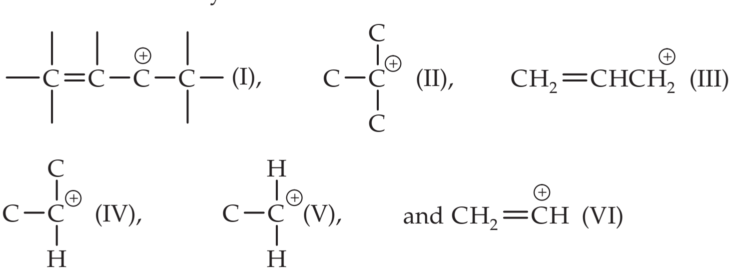
41. Which of the following free radicals is the most stable?

(a) Vinylic (b) Allylic (c) 1° (d) 2°

42. The chlorination of propene at 400°C in the gaseous phase gives

(a) $ClCH_2{-}\underset{\displaystyle Cl}{\underset{|}{CH}}{-}CH_3$ (b) $CH_3{-}\underset{\displaystyle Cl}{\underset{|}{CH}}{-}CH_3$
(c) $CH_2{=}CH{-}CH_2Cl$ (d) $ClCH_2{-}CH_2{-}CH_3$

43. The order of stability of the carbocations



is

(a) VI > V > IV > III > II > I (b) I > II > III > VI > V > IV
(c) V > VI > III > IV > I > II (d) I > II > III > IV > V > VI

44. Arrange the compounds

$CH_2{=}CH{-}CH_3$ (I), $CH_2{=}CH{-}CH{=}CH_2$ (II),
$HC{\equiv}C{-}CH{=}CH_2$ (III) and $HC{\equiv}C{-}C{\equiv}CH$ (IV)

in order of increasing carbon-carbon single-bond length.

(a) I > II > III > IV (b) II > I > IV > III
(c) IV > III > II > I (d) I > II > IV > III

45. In which of the following compounds is the hybridization state of the atoms in the carbon-carbon single bonds sp-sp?

(a) $HC{\equiv}C{-}C{\equiv}CH$ (b) $HC{\equiv}C{-}CH{=}CH_2$
(c) $HC{\equiv}C{-}CH_3$ (d) $CH_2{=}CH{-}CH{=}CH_2$

46. The angle strains at the CH_2 groups in cyclopropane (I), cyclobutane (II) , cyclopentane (III) and cyclohexane (IV) follow the order

(a) IV > III > II > I (b) I > II > III > IV
(c) II > I > IV > III (d) III > II > I > IV

47. The product obtained in the reaction

$$CF_3{-}CH{=}CH_2 + HCl \longrightarrow$$

is

(a) $CF_3CH_2{-}CH_2Cl$ (b) $CF_3CHClCH_3$
(c) $CF_3CHCl{-}CH_2Cl$ (d) none of these

48. The order of reactivity of F, Cl, Br and I in substitution reactions is

(a) F > Cl > Br > I (b) Cl > Br > I > F
(c) I > Br > Cl > F (d) Cl = Br > I > F

49. Which of the following compounds has the highest boiling point?

(a) *n*-Octane (b) Iso-octane
(c) *n*-Butane (d) 2,2,3,3-Tetramethylbutane

50. Which of the following conditions gives the best yield of ethyl chloride?

(a) $C_2H_6 \text{ (excess)} + Cl_2 \xrightarrow{\text{uv light}}$

(b) $C_2H_6 + Cl_2 \text{ (excess)} \xrightarrow{\text{uv light}}$

(c) $C_2H_6 + Cl_2 \xrightarrow{\text{uv light}}$

(d) $C_2H_6 + Cl_2 \xrightarrow[\text{room temp.}]{\text{darkness}}$

51. Which of the following compounds will have zero dipole moment?

(a) *cis*-1,2-Dichloroethylene (b) *trans*-1,2-Dichloroethylene

(c) 1,1-Dichloroethylene (d) None of these

52. On treatment with alcoholic potassium hydroxide, *n*-propyl bromide gives

(a) propane (b) propene
(c) propyne (d) propanol

53. How many types of carbon atoms are present in 2,2,3-trimethylpentane?

(a) One (b) Two
(c) Three (d) Four

54. In ethane, the H—C—C bond angle is

(a) 109.5° (b) 109° (c) 180° (d) 120°

55. The shape of the methane molecule is

(a) trigonal planar (b) square planar
(c) tetrahedral (d) linear

56. Methane as well as ethane can be obtained in one step from

(a) CH_3OH (b) C_2H_5OH (c) CH_3I (d) C_2H_2

57. The reaction of methyl magnesium bromide with ethyl alcohol gives

(a) methyl alcohol (b) methane
(c) isopropyl alcohol (d) ethane

58. The preparation of an alkane from an alkyl halide by reaction with zinc is known as the

(a) Wurtz reaction (b) Cannizzaro reaction
(c) Frackland reaction (d) Kolbe reaction

59. The boiling point of a branched alkane as compared to that of a straight-chain isomer is

(a) high (b) low
(c) equal (d) independent of branching

60. The order of reactivity of the hydrogens in isopentane is

(a) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3}$ (b) $\overset{\circ}{1} = \overset{\circ}{2} > \overset{\circ}{3}$ (c) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1}$ (d) $\overset{\circ}{3} > \overset{\circ}{1} > \overset{\circ}{2}$

61. The halogenation of alkanes is an example of

(a) nucleophilic substitution (b) electrophilic substitution
(c) oxidation (d) free-radical substitution

62. Which of the following alkanes gives only one monochlorinated product?

(a) $CH_3CH_2CH_3$ (b) $CH_3CH_2CH_2CH_3$
(c) $(CH_3)_4C$ (d) $CH_3(CH_2)_3CH_3$

63. A liquid hydrocarbon is converted to a mixture of gaseous hydrocarbons by

(a) hydrolysis (b) oxidation
(c) distillation in vacuum (d) cracking

64. Which of the following compounds has the lowest boiling point?

(a) $CH_3CH_2CH_2CH_2CH_2CH_3$ (b) $CH_3CH_2\underset{\displaystyle CH_3}{\underset{|}{CH}}—CH_2CH_3$

(c) $CH_3CH_2\overset{\displaystyle CH_3}{\overset{|}{\underset{\displaystyle CH_3}{\underset{|}{C}}}}—CH_3$ (d) $CH_3—\underset{\displaystyle CH_3}{\underset{|}{CH}}—\underset{\displaystyle CH_3}{\underset{|}{CH}}—CH_3$

65. Which of the following is the isobutyl group?

(a) $CH_3CH_2CH_2CH_2—$ (b) $CH_3—CH_2—\underset{|}{CH}—CH_3$

(c) $\begin{matrix} CH_3\diagdown \\ CH_3\diagup \end{matrix}CHCH_2—$ (d) $CH_3—\overset{\displaystyle CH_3}{\overset{|}{\underset{\displaystyle CH_3}{\underset{|}{C}}}}—$

66. Which of the following compounds has three $\overset{\circ}{1}$, one $\overset{\circ}{2}$ and one $\overset{\circ}{3}$ carbon atom?

(a) $CH_3(CH_2)_2CH_3$ (b) $CH_3CH(CH_3)CH_3$
(c) $CH_3(CH_2)_3CH_3$ (d) $CH_3CH(CH_3)CH_2CH_3$

67. The ease of formation of free radicals follows the order

(a) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1} > \dot{C}H_3$ (b) $\dot{C}H_3 > \overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3}$
(c) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3} > \dot{C}H_3$ (d) $\overset{\circ}{2} > \overset{\circ}{1} > \overset{\circ}{3} > \dot{C}H_3$

68. Which of the following is correct regarding the stability of carbocations?

(a) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1}$ (b) $\overset{\circ}{3} < \overset{\circ}{2} < \overset{\circ}{1}$
(c) $\overset{\circ}{2} > \overset{\circ}{1} > \overset{\circ}{3}$ (d) $\overset{\circ}{2} > \overset{\circ}{3} > \overset{\circ}{1}$

69. The shape of the ethylene molecule is

(a) linear (b) tetrahedral
(c) pyramidal (d) planar

70. The bond angle H—C—H of alkenes is equal to

(a) 109°28′ (b) 120° (c) 60° (d) 180°

71. What type of hybridization occurs in ethylene?

(a) sp (b) sp^3 (c) sp^2 (d) sp^3d

72. The compound having one C—C σ-bond, one C—C π-bond and four C—H σ-bonds is

(a) $CH_3—CH═CH_2$ (b) $CH_2═CH_2$

(c) $CH_2═CH—CH═CH_2$ (d) $CH_2═CH—CH_3$

73. The compound having a C—C bond distance of 1.54 Å can be

(a) $CH_3—CH_3$ (b) $CH_3—CH_2—CH_3$

(c) $CH_2═CH_2$ (d) $CH≡CH$

74. The vinyl group is represented by

(a) $CH_2═CH—$ (b) $CH_2═CH—CH_2—$

(c) $CH_3—CH═CH—CH_2—$ (d) $CH_3—CH═CH—$

75. Among the following,

(a) $CH_3CH═CH_2$ (b) $CH_2═C═CH_2$

(c) $CH_3C≡CH$ (d) $CH_2═CH—CH═CH_2$

has sp- as well as sp^2-hybridized carbon atoms.

76. The compound having a conjugated double bond is

(a) butylene (b) propylene

(c) isobutylene (d) butadiene

77. The compound having only sp^2-hybridized carbon atoms is

(a) 1-butene (b) 2-butene

(c) propene (d) butadiene

78. Which of the following has the lowest heat of hydrogenation per mole?

(a) *cis*-2-Butene (b) *trans*-2-Butene

(c) 1-Butene (d) 1,3-Butadiene

79. On reacting with alcoholic potash, 1-chlorobutane gives

(a) 1-butene (b) 1-butanol

(c) 2-butanol (d) 2-butene

80. On being heated with alcoholic potassium hydroxide, neopentyl bromide gives mainly

(a) 2-methyl-2-butene (b) 2-methyl-1-butene

(c) 2-butene (d) 2,2-dimethyl-1-butene

81. Dehydrohalogenation can be brought about by using

(a) an aqueous solution of KOH (b) an alcoholic solution of KOH

(c) concentrated H_2SO_4 (d) zinc dust

82. Sodium ethoxide is a specific reagent for
(a) dehydrogenation (b) dehydration
(c) dehydrohalogenation (d) dehalogenation

83. The treatment of a mixture of 1-chloropropane and 2-chloropropane with alcoholic KOH gives
(a) 1-propene (b) 2-propene
(c) isopropylene (d) none of these

84. Alkanes and alkenes can both be obtained by
(a) Wurtz reaction (b) Frackland reaction
(c) Kolbe's electrolytic method (d) Williamson synthesis

85. In the reaction of 2-halogen–substituted butane with concentrated H_2SO_4 at 475 K, the major product obtained is
(a) 1-butene
(b) 2-butene
(c) both 1- and 2-butene
(d) the product ratio depends on the halogen

86. 1-Butene exhibits
(a) geometrical isomerism (b) optical isomerism
(c) position isomerism (d) none of these

87. The most common reactions of alkenes are those of
(a) nucleophilic substitution (b) electrophilic substitution
(c) electrophilic addition (d) nucleophilic addition

88. The conversion of ethylene into ethane can be effected by
(a) nascent hydrogen (b) Zn + HCl
(c) Raney nickel and hydrogen (d) Clemmensen reduction

89. The main product of the reaction of 1-butene with excess bromine is
(a) 1,1-dibromobutane (b) 1,2-dibromobutane
(c) 2,2-dibromobutane (d) perbromobutane

90. The course of the reaction

$$CH_3CH{=}CH_2 + HBr \longrightarrow CH_3CHBrCH_3$$

is predicted by
(a) the Baeyer strain theory (b) the Markovnikov rule
(c) the peroxide effect (d) Thiel's theory

91. The reaction of 1-butene with HBr in the presence of peroxide gives
(a) 2-bromobutane (b) 1-bromobutane
(c) 1,1-dibromobutane (d) 1,2-dibromobutane

92. The major product of the reaction of $CH_3CH_2CHBrCH_3$ with alcoholic KOH is

(a) 1-butene (b) 2-butene (c) butane (d) butyne-1

93. The number of enantiomeric pairs that can be produced by the monochlorination of 2-methylbutane is

(a) one (b) two (c) three (d) four

94. The intermediate formed during the addition of HCl to propene in the presence of peroxide is

(a) $CH_3\dot{C}HCH_2Cl$ (b) $CH_3CH_2\dot{C}H_2$

(c) $CH_3\overset{+}{C}HCH_3$ (d) $CH_3CH_2\overset{+}{C}H_2$

95. The addition of HI in the presence of a peroxide does not lead to anti-Markovnikov behaviour because

(a) the iodine free radicals formed readily combine with each other to give an I_2 molecule

(b) the HI bond is too strong to be broken homolytically

(c) HI is a reducing agent

(d) I combines with H to give back HI

96. The peroxide effect in anti-Markovnikov addition involves

(a) the heterolytic fission of the double bond

(b) the homolytic fission of the double bond

(c) a free-radical mechanism

(d) an ionic mechanism

97. Orlon is obtained from

(a) vinyl chloride (b) vinyl cyanide

(c) 1,3-butadiene (d) tetrafluoroethylene

98. The order of stability of the alkenes

$$\underset{\text{I}}{R_2C{=}CR_2},\ \underset{\text{II}}{R_2C{=}CHR},\ \underset{\text{III}}{R_2C{=}CH_2},$$

$$\underset{\text{IV}}{RCH{=}CHR} \text{ and } \underset{\text{V}}{RCH{=}CH_2}$$

is

(a) I > II > III > IV > V (b) I = II > III > IV > V

(c) II > I > IV > III > V (d) V > IV > III > I > II

99. In dehydrohalogenation, the order of reactivity of RX is

(a) $\mathring{3} > \mathring{2} > \mathring{1}$ (b) $\mathring{1} > \mathring{2} > \mathring{3}$

(c) $\mathring{2} > \mathring{3} > \mathring{1}$ (d) $\mathring{3} = \mathring{2} > \mathring{1}$

100. The reaction of HCl with propene in the presence of benzoyl peroxide yields

(a) 2-chloropropane (b) *n*-propyl chloride

(c) allyl chloride (d) There is no reaction.

101. 

In the above reaction, X is

(a) O_3 (b) $KMnO_4$

(c) HNO_3 (d) O_2

102. Ethylene reacts with a dilute alkaline $KMnO_4$ solution to give

(a) HCHO (b) oxalic acid

(c) glycol (d) ethyl alcohol

103. Which of the following is obtained by addition polymerization?

(a) PVC (b) Terylene

(c) Nylon (d) Polyamide

104. Polythene is obtained by the polymerization of

(a) butadiene (b) isoprene

(c) ethylene (d) styrene

105. Teflon is obtained from

(a) difluoroethene (b) monofluoroethene

(c) tetrafluoroethene (d) tetrafluoroethane

106. In the sequence of reactions,

$$CH_3CH_2CH_2OH \xrightarrow{PCl_5} A \xrightarrow[\text{KOH}]{\text{alc.}} B$$

the product B is

(a) propyne (b) propylene

(c) propane (d) propanol

107. In the sequence of reactions,

$$CH_3CH_2CH_2OH \xrightarrow{PCl_5} A \xrightarrow{\text{aq. KOH}} B$$

the product B is

(a) propylene (b) propane

(c) propyne (d) propanol

108. Ethylene chlorohydrin is obtained from ethylene by the action of

(a) dry chlorine gas (b) dry HCl gas

(c) dilute HCl (d) a solution of chlorine in water

109. The reaction of $RCH{=}CH_2$ with B_2H_6 followed by oxidation with alkaline H_2O_2 gives

(a) $RCH(OH)CH_2OH$ (b) $R{-}COCH_3$

(c) RCH_2CH_2OH (d) RCH_2CHO

110. The major product obtained by the treatment of propyne with aqueous H_2SO_4 in the presence of $HgSO_4$ is

(a) propanal (b) acetone

(c) propanol (d) propyl hydrogen sulphate

111. Butadiene has

(a) only sp^2-hybridized carbon atoms

(b) only sp-hybridized carbon atoms

(c) sp- as well as sp^2-hybridized carbon atoms

(d) sp-, sp^2- and sp^3-hybridized carbon atoms

112. Which of the following reactions will yield 2,2-dibromopropane?

(a) $HC{=}CH + 2HBr \longrightarrow$ (b) $CH_3CH{=}CHBr + HBr \longrightarrow$

(c) $CH_3C{\equiv}CH + 2HBr \longrightarrow$ (d) $CH_3CH{=}CH_2 + HBr \longrightarrow$

113. The reaction of propene with chlorine gas at about 500°C gives

(a) $CH_2ClCH{=}CH_2$ (b) $CH_3CHClCH_2Cl$

(c) $CH_2ClCHCl{-}CH_2Cl$ (d) a mixture of (a) and (b)

114. The major product of the debromination of *meso*-dibromobutane is

(a) *n*-butane (b) 1-butene

(c) *trans*-2-butene (d) *cis*-2-butene

115. Chloroprene is

(a) 3-chloro-2,3-butadiene (b) 2-chloro-1,3-butadiene

(c) 2,3-dichlorobutadiene (d) none of these

116. A compound having a bond angle of 180° is a/an

(a) alkane (b) alkene

(c) cycloalkane (d) alkyne

117. 1-Buten-3-yne contains

(a) six σ- and four π-bonds (b) five σ- and three π-bonds

(c) seven σ- and three π-bonds (d) eight σ- and two π-bonds

118. How many structures may C_5H_8 represent?

(a) Two (b) Four

(c) Five (d) Six

119. The conversion of 3-hexyne into *trans*-3-hexene can be effected by

(a) Na/liquid NH_3 (b) H_2/Lindlar's catalyst

(c) Clemmensen reduction (d) $LiNH_2$

120. The relative acidities of H_2O, ROH, $HC\equiv CH$ and NH_3 are of the order

(a) $H_2O > ROH > HC\equiv CH > NH_3$

(b) $HC\equiv CH > H_2O > ROH > NH_3$

(c) $ROH > H_2O > HC\equiv CH > NH_3$

(d) $ROH = H_2O > HC\equiv CH > NH_3$

121. In the reaction $CH_3CH_2CCl_2CH_3 \xrightarrow{X} CH_3C\equiv CCH_3$, the reagent X is

(a) KOH/C_2H_5OH (b) Zn

(c) HCl/H_2O (d) Na

122. The reduction of 3-hexyne with H_2/Lindlar's catalyst gives predominantly

(a) *n*-hexane

(b) *trans*-3-hexene

(c) *cis*-3-hexene

(d) a mixture of *cis*- and *trans*-3-hexene

123. The catalyst required for the reaction

$$HC\equiv CH + \text{dil. } H_2SO_4 \xrightarrow{\text{catalyst}} CH_3CHO$$

is

(a) $HgSO_4$ (b) Pd (c) Pt (d) $AlCl_3$

124. In the reaction

$$CH_3C\equiv CCH_3 \xrightarrow[\text{(ii) } H_2O/Zn]{\text{(i) X}} H_3C-\underset{\underset{O}{\|}}{C}-\underset{\underset{O}{\|}}{C}-CH_3$$

X is

(a) O_2 (b) O_3

(c) HNO_3 (d) $KMnO_4$

125. The decreasing order of the strength of the bases OH^-, NH_2^-, $H-C\equiv C^-$ and $CH_3-\bar{C}H_2$ is

(a) $H-C\equiv C^- > CH_3-\bar{C}H_2 > NH_2^- > OH^-$

(b) $CH_3-\bar{C}H_2 > NH_2^- > H-C\equiv C^- > OH^-$

(c) $NH_2^- > H-C\equiv C^- > OH^- > CH_3-\bar{C}H_2$

(d) $OH^- > NH_2^- > H-C\equiv C^- > CH_3-\bar{C}H_2$

126. In which of the following conditions does the reaction

$$HC{\equiv}CH \longrightarrow CHCl_2CHO$$

take place?

(a) $HC{\equiv}CH \xrightarrow{HOCl}$

(b) $HC{\equiv}CH \xrightarrow[\text{peroxide}]{HOCl}$

(c) $HC{\equiv}CH \xrightarrow{Cl_2}$

(d) $HC{\equiv}CH \xrightarrow[\text{oxidizing agent}]{Cl_2}$

127. In which of the following conditions does the reaction

$$HC{\equiv}CH + CH_3OH \longrightarrow CH_3O{-}C{\equiv}CH$$

take place?

(a) $HC{\equiv}CH + CH_3OH \xrightarrow[160\text{–}200°C]{KOMe}$

(b) $HC{\equiv}CH + CH_3OH \xrightarrow{\text{conc. } H_2SO_4}$

(c) $HC{\equiv}CH + CH_3OH \xrightarrow{\text{anhyd. } ZnCl_2}$

(d) $HC{\equiv}CH + CH_3OH \xrightarrow[ClHC{=}CHCl]{\text{dil. } HCl}$

128. In the reaction $CH{\equiv}CH \xrightarrow{X} Cl_2CH{-}CHCl_2$, X is

(a) NaOCl

(b) Cl_2/CCl_4

(c) chlorine water

(d) NaCl

129. Which of the following will not react with an ammoniacal silver nitrate solution?

(a) $CH_3C{\equiv}CH$

(b) $(CH_3)_2CH{-}C{\equiv}CH$

(c) $CH_3C{\equiv}CCH_3$

(d) $HC{\equiv}CH$

130. The addition of HCN to acetylene in the presence of $Ba(CN)_2$ as catalyst gives

(a) ethyl cyanide

(b) 1,1-dicyanoethane

(c) divinyl cyanide

(d) vinyl cyanide

131. Which reagent is used to distinguish 1-butyne from 2-butyne?

(a) HCl

(b) Br_2/CCl_4

(c) Baeyer's reagent

(d) Ammoniacal cuprous chloride

132. Which reagent is the most useful for distinguishing compound I from the rest of the compounds?

$CH_3CH_2C{\equiv}CH$	$CH_3C{\equiv}CCH_3$	$CH_3CH_2CH_2CH_3$	$CH_3CH{=}CH_2$
I	II	II	IV

(a) Alkaline $KMnO_4$

(b) Br_2/CCl_4

(c) Br_2/CH_3COOH

(d) Ammoniacal $AgNO_3$

133. A compound decolourizes an alkaline $KMnO_4$ solution but does not react with an ammoniacal $AgNO_3$ solution. It is

(a) benzene (b) butyne-1 (c) butyne-2 (d) acetylene

134. A compound (C_5H_8) reacts with ammoniacal $AgNO_3$ to give a white precipitate and reacts with an excess of $KMnO_4$ solution to give $(CH_3)_2CH—COOH$. The compound is

(a) $CH_2{=}CH—CH{=}CH—CH_3$ (b) $(CH_3)_2CH—C{\equiv}CH$
(c) $CH_3(CH_2)_2C{\equiv}CH$ (d) $(CH_3)_2C{=}C{=}CH_2$

135. Which among the following is the most strained cycloalkane?

(a) Cyclopropane (b) Cyclobutane
(c) Cyclopentane (d) Cyclohexane

136. The tendency of cyclopropane (I), cyclobutane (II) and cyclopentane (III) to form addition compounds is in the order

(a) I > II > III (b) I = II > III
(c) I > II = III (d) I = III > II

137. The stability of the cycloalkanes cyclopropane (I), cyclobutane (II), cyclopentane (III) and cyclohexane (IV) is in the order

(a) II > I > III > IV (b) VI > III > II > I
(c) II = I > III > IV (d) II > I = III > IV

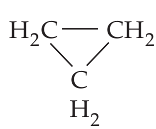
138. Which among the following has the greatest bond angle?

(a) Cyclopropane (b) Cyclobutane
(c) Cyclopentane (d) Cyclohexane

139. Which of the following is the most reactive cycloalkane?

(a) Cyclopropane (b) Cyclobutane
(c) Cyclopentane (d) Cyclohexane

140. $BrCH_2—CH_2—CH_2Br$ reacts with Na in the presence of ethanol at 100°C to produce

(a) $BrCH_2—CH{=}CH_2$ (b) $CH_2{=}C{=}CH_2$
(c) 

(d) all of these

141. The conformation of cyclohexane is of

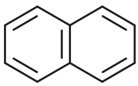
(a) the chair form (b) the boat form
(c) the half-chair form (d) the twist-boat form
(e) an equilibrium of all the forms

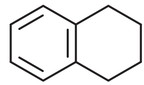
142. 3,5-Dimethylcyclopentene, on ozonolysis, yields

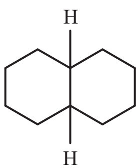
(a) only an aldehyde (b) only a ketone

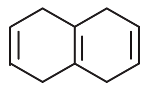
(c) an aldehyde and a ketone (d) a dialdehyde

143. Which of the following represents decalin?

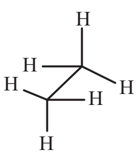
(a) 

(b) 

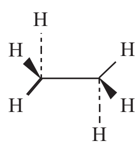
(c) 

(d) 

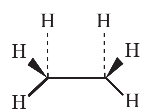
144. Which of the following represents the staggered conformation of ethane?



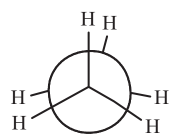
I



II



III



IV

(a) I and II (b) I, II and III

(c) I and III (d) II, III and IV

145. The order of reactivity of the halogens (Cl_2, Br_2, I_2, F_2) towards methane is

(a) $F_2 > Cl_2 > Br_2 > I_2$ (b) $F_2 > Br_2 > Cl_2 > I_2$

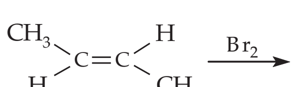
(c) $F_2 > I_2 > Br_2 > Cl_2$ (d) $I_2 > F_2 > Cl_2 > Br_2$

146. The reaction of propene with chlorine at 600°C gives

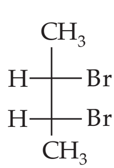
(a) $ClCH_2CH{=}CH_2$ (b) $CH_3CHCl{-}CH_2Cl$

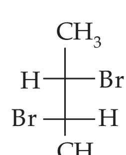
(c) $CH_3CHCl{-}CH_3$ (d) $ClCH_2CH_2CH_2Cl$

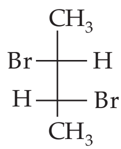
147. The product obtained in the reaction

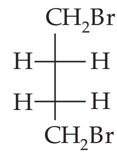


is

(a) 

(b) 

(c) 

(d) 

148. Arrange the following in order of increasing acidity.

CH_4, NH_3, H_2O, HF, HCl, H_2S

(a) $HF < HCl < H_2S < H_2O < NH_3 < CH_4$
(b) $H_2O < NH_3 < CH_4 < H_2S < HF < HCl$
(c) $HCl < H_2S < HF < H_2O < NH_3 < CH_4$
(d) $CH_4 < NH_3 < H_2O < HF < H_2S < HCl$

149. The hyperconjugative effect in the compounds

$\underset{\text{I}}{CH_3CH{=}CH_2}$ $\quad$ $\underset{\text{II}}{(CH_3)_2CH{=}CH_2}$ $\quad$ $\underset{\text{III}}{(CH_3)_3C{-}CH{=}CH_2}$

is of the order

(a) I > II > III
(b) III > II > I
(c) I > III> II
(d) II > III > I

150. In the reaction of ethyl alcohol with an excess of concentrated H_2SO_4 at 440 K to give ethylene, the following steps are involved.

(a) $CH_3CH_2OH + H^+ \rightleftharpoons CH_3CH_2{-}\overset{+}{O}H_2$
(b) $CH_3CH_2\overset{+}{O}H_2 \longrightarrow CH_3{-}\overset{+}{C}H_2 + H_2O$
(c) $CH_3{-}\overset{+}{C}H_2 \longrightarrow CH_2{=}CH_2$
(d) $CH_3CH_2OH \xrightarrow{-H_2O} CH_2{=}CH_2$

Of the above, which is the fast step?

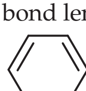
151. The stability of the alkenes

$\underset{\text{I}}{CH_2{=}CH_2}$ $\quad$ $\underset{\text{II}}{CH_3CH{=}CH_2}$ $\quad$ $\underset{\text{III}}{(CH_3)_2C{=}CH_2}$ $\quad$ $\underset{\text{IV}}{(CH_3)_2{=}CHCH_3}$

decreases in the order

(a) IV > III > II > I
(b) I > II > III > IV
(c) I > III > II > IV
(d) II > III > I > IV

152. The carbon-carbon bond length in the compounds

$CH_2{=}CH_2$  $CH_3{-}CH_3$ $CH{\equiv}CH$

I   II   III   IV

follows the order

(a) III < II < I < IV (b) IV < I < II < III
(c) I < II < III < IV (d) I < IV < III < II

153. What is the order of the ease of formation of the following free radicals?

(a) Allyl > $\overset{\circ}{3}$ > $\overset{\circ}{2}$ > $\overset{\circ}{1}$ > $\dot{C}H_3$ > vinyl

(b) Vinyl > $\dot{C}H_3$ > $\overset{\circ}{1}$ > $\overset{\circ}{2}$ > $\overset{\circ}{3}$ > allyl

(c) $\overset{\circ}{1}$ > $\overset{\circ}{2}$ > $\overset{\circ}{3}$ > allyl > $\dot{C}H_3$ > vinyl

(d) $\dot{C}H_3$ > $\overset{\circ}{1}$ > $\overset{\circ}{2}$ > $\overset{\circ}{3}$ > allyl> vinyl

154. A compound C_4H_8 decolourizes a $KMnO_4$ solution. How many structures are possible for this compound?

(a) 3 (b) 4 (c) 2 (d) 5

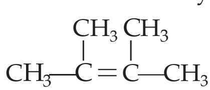
155. Which of the following compounds will exhibit geometrical isomerism?

(a) Propene (b) Isobutylene
(c) 1,2-Dibromoethene (d) 1-Butene

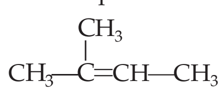
156. The normal C═C bond length in ethylene is 1.49 Å and the normal C—C bond length in propane is 1.54 Å. What will be the bond length of the C_2—C_3 single bond in propene (CH_3—CH_2═CH_2)?

(a) 1.49 Å (b) 1.54 Å
(c) < 1.49 Å (d) Between 1.49 Å and 1.54 Å

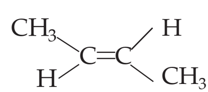
157. The relative stability of the compounds



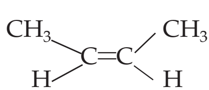
I



II



III



IV

CH_3—CH═CH_2

V

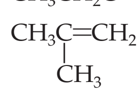
CH_2═CH_2

VI

is of the order

(a) I > II > III > IV > V > VI (b) VI > V > IV > III > II > I
(c) I > III > V > II > IV > VI (d) II > I > IV > III > V > VI

158. An organic compound decolourizes bromine in CCl_4 and can be reduced catalytically. Also, it gives a precipitate with ammoniacal cuprous chloride. The compound can be

(a) CH_3—CH═CH—CH_3 (b) CH_3CH_2C≡CH
(c) CH_3CH═CH_2 (d) 

159. $CH_3-CH_2-\underset{\underset{Br}{|}}{CH}-CH_3 \xrightarrow[\text{alcoholic}]{\overline{O}H}$

The product obtained in the above reaction is

(a) $CH_3CH{=}CHCH_3$

(b) $CH_3CH_2CH{=}CH_2$

(c) a mixture of $CH_3CH{=}CHCH_3$ and $CH_3CH_2CH{=}CH_2$

(d) there is no reaction

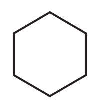
160. In the formation of cyclohexane from 1-hexene, the entropy of cyclohexane is

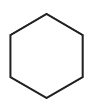
(a) more than that of 1-hexene

(b) less than that of 1-hexene

(c) equal to that of 1-hexene

(d) more or less than that of 1-hexene depending on the conditions of the reaction

161. (A) $CH_3-CH_2-CH_2-CH_2-CH{=}CH_2 \longrightarrow$ 

(B) $3CH_2{=}CH_2 \longrightarrow$ 

Consider the reactions (A) and (B). The entropy change will be

(a) more in reaction A than in reaction B

(b) more in reaction B than in reaction A

(c) equal in both reactions

(d) zero in both reactions

162. The bond dissociation energies of the following

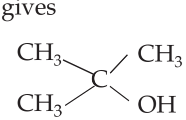
CH_3-H	CH_3CH_2-H	$CH_2{=}CH-CH_2-H$	C_6H_5-H
I	II	III	IV

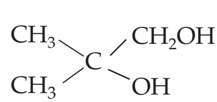
vary in the order

(a) I > II > III > IV (b) IV > III > II > I

(c) IV > I > II > III (d) II > I > IV > III

163. The reaction of isobutylene with water in the presence of 10% H_2SO_4 at 25°C gives

(a) 

(b) 

(c) $\begin{matrix} CH_3 \diagdown \\ \quad C{=}O \\ CH_3 \diagup \end{matrix}$ (d) none of these

164. Isobutylene reacts with HBr to give *t*-butyl bromide. The intermediate formed in this reaction is

(a) a *t*-butyl cation
(b) an isobutyl cation
(c) a mixture of *t*- and isobutyl cations
(d) The addition does not take place through a cation intermediate.

165. Tri-*n*-propylborane can be converted into propyl alcohol by reaction with

(a) hydrogen peroxide at 25–30°C
(b) a dilute acid at reflux temperature
(c) a dilute alkali at reflux temperature
(d) none of these

166. Which of the following represents the hybrid structure of acrolein?

(a) $CH_2{=}CH-CH{=}\ddot{O}{:}$ (b) $CH_2{=}CH-\overset{\oplus}{C}H{=}\ddot{\underset{..}{O}}{:}^{\ominus}$

(c) $\overset{\oplus}{C}H_2{=}CH{=}CH-\ddot{\underset{..}{O}}{:}^{\ominus}$ (d) $\overset{\delta\oplus}{C}H_2{\dashrightarrow}CH{\dashrightarrow}\overset{\delta\oplus}{C}H{\dashrightarrow}\overset{2\delta\ominus}{O}$

167. The rate of abstraction of hydrogen from $\overset{\circ}{3}$, $\overset{\circ}{2}$ and $\overset{\circ}{1}$ carbon atom follows the order

(a) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1}$ (b) $\overset{\circ}{2} > \overset{\circ}{3} > \overset{\circ}{1}$ (c) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3}$ (d) $3° > 1° > 2°$

168. The amount of energy needed to form the radicals $\dot{C}H_3$, $\overset{\circ}{1}$, $\overset{\circ}{2}$ and $\overset{\circ}{3}$ decreases in the order

(a) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1} > \dot{C}H_3$ (b) $\dot{C}H_3 > \overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3}$
(c) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3} > \dot{C}H_3$ (d) $\dot{C}H_3 > \overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1}$

169. Arrange the free radicals vinyl ($H_2C{=}\dot{C}H$), allyl $H_2C{=}CH{-}\dot{C}H_2$ and benzyl ($C_6H_5{-}\dot{C}H_2$) in order of their stability.

(a) Benzyl > allyl > vinyl (b) Allyl > vinyl > benzyl
(c) Vinyl > allyl > benzyl (d) Vinyl > benzyl > allyl

170. The ease of abstraction of allylic, $\overset{\circ}{3}$, $\overset{\circ}{2}$, $\overset{\circ}{1}$, CH_4 and vinylic hydrogens follows the order

(a) allylic > $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1} > CH_4$ > vinylic
(b) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1} > CH_4$ > allylic > vinylic
(c) $CH_4 > \overset{\circ}{3} > \overset{\circ}{1} > \overset{\circ}{2}$ > vinylic > allylic
(d) vinylic > allylic > $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3} > CH_4$

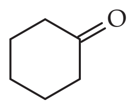
• *Type 2* •

Choose the correct options. More than one option is correct.

171. Which of the following compounds exhibit geometrical isomerism?

(a) $CH_3CH{=}CH{-}COOH$ (b) $Br{-}CH{=}CH{-}Br$

(c) $C_6H_5CH{=}NOH$ (d)



172. Which of the following statements are correct?

(a) 1,1-Dichloroethane exhibits geometrical isomerism.

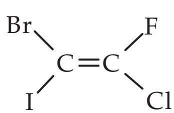
(b) 1,2-Dichloroethane shows geometrical isomerism.

(c) 1-Butene exhibits geometrical isomerism.

(d) Isobutylene does not show geometrical isomerism.

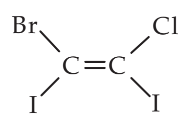
173. Which of the following notations are correct?

(a)



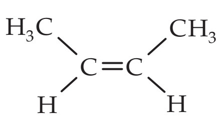
(Z)

(b)



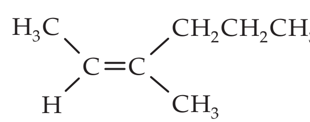
(E)

(c)



(Z)

(d)



(E)

174. Which of the following has dipole moment?

(a) *cis*-2-butene

(b) *trans*-2-butene

(c) *cis*-1,2-dibromoethene

(d) *trans*-1,2-dibromoethene

175. Which of the following statements are correct about cis and trans isomers?

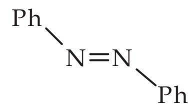
(a) *cis*-2-butene can be converted into *trans*-2-butene by irradiation.

(b) In general, trans isomers have zero dipole moment.

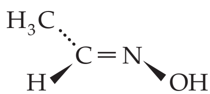
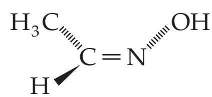
(c) On heating, fumaric acid (a trans acid) gives an anhydride.

(d) On heating, maleic acid (a cis acid) gives an anhydride.

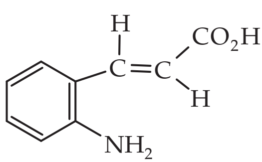
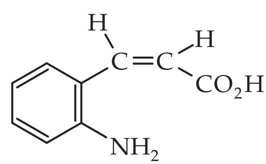
176. For which of the following pairs of compounds are the correct notations given?

(a)  and 

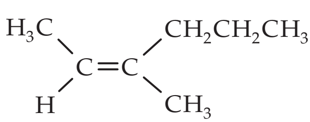
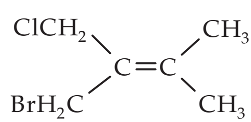
Anti-azobenzene Syn-azobenzene

(b)  and 

Syn-acetaldoxime Anti-acetaldoxime

(c)  and 

Trans -*o*-aminocinnamic acid *Cis* -*o*-aminocinnamic acid

(d)  

Z-isomer E-isomer

177. Which of the following statements are correct?

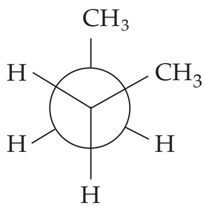
(a) $CH_3CH_2CH_2CH_2OH$ and $CH_3\overset{CH_3}{\overset{|}{C}}HCH_2OH$ represent chain isomerism.

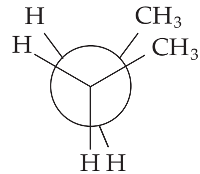
(b) $CH_3CH_2CH_2CH{=}CH_2$ and $CH_3CH_2CH{=}CHCH_3$ are examples of position isomerism.

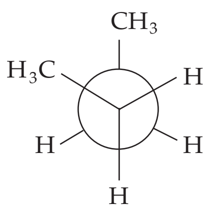
(c) $C_2H_5OCH_3$ and $CH_3CH_2CH_2OH$ represent functional-group isomerism.

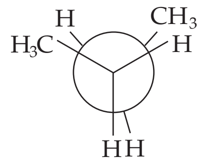
(d) $CH_3CH_2NH_2$ and CH_3NHCH_3 are examples of metamerism.

178. Which of the following represent staggered conformations of *n*-butane?

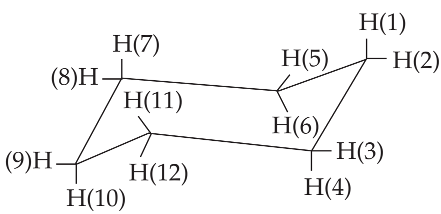
(a)


(b)


(c)


(d)


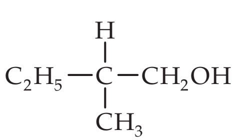
179. In the chair conformation of cyclohexane (given below)

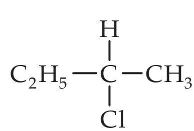


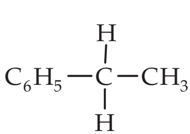
which of the following hydrogens (marked 1–12 in the representation above) are axial?

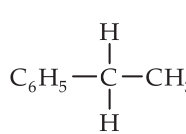
(a) 1
(b) 2
(c) 9
(d) 10

180. Which of the following have chiral carbon?

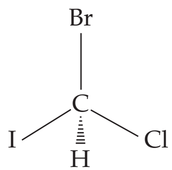
(a)


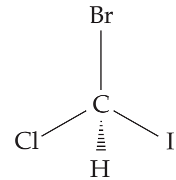
(b)


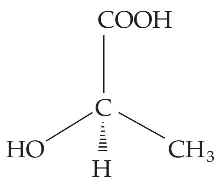
(c)


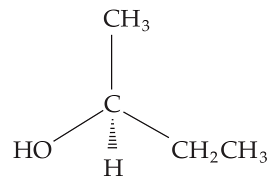
(d)


181. Which of the following representations have an R configuration?

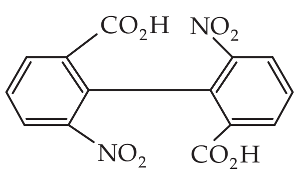
(a) 

(b) 

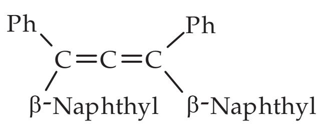
(c) 

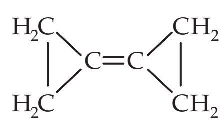
(d) 

182. Which of the following compounds exhibit optical isomerism?

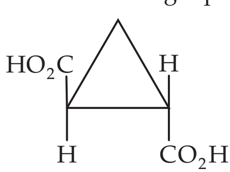
(a) 

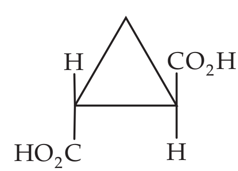
(b) $CH_2{=}C{=}CH_2$

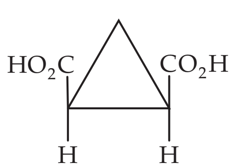
(c) 

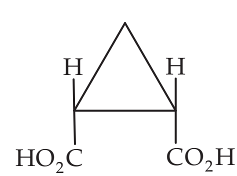
(d) 

183. Which of the following represent a pair of enantiomers?

(a) 

(b) 

(c) 

(d) 

184. 2-Bromo-3-phenylpropane can be synthesised by

(a) $C_6H_5CH_2CH(OH)CH_3 + PBr_3 \longrightarrow$

(b) $C_6H_5CH{=}CHCH_3 + HBr + \text{benzoyl peroxide} \longrightarrow$

(c) $C_6H_5CH_2CH_2CH_3 + Br_2 + \text{light} \longrightarrow$

(d) none of these

185. Which of the following structures can exist as cis-trans isomers?

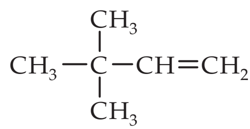
(a) $CH_3CH_2CH_2CH{=}CHCH_2CH_3$

(b) $CH_3CH_2CH_2CH_2CH_2CH_2CH{=}CH_2$

(c) $CH_3CH_2CH{=}CHCH_2CH_2CH_2CH_3$

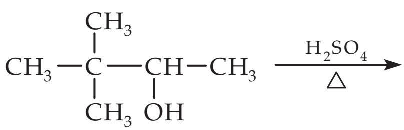
(d) $CH_2{=}CHCH_2CH_2CH_2CH_2CH_3$

186. Which of the following reactions are expected to give

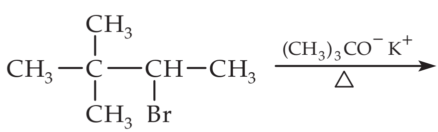


in yields of more than 50%?

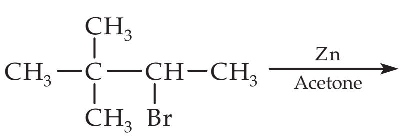
(a)



(b)



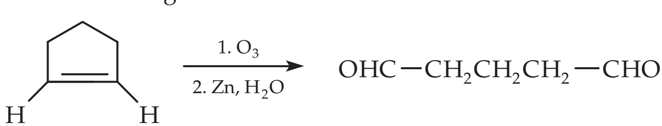
(c)



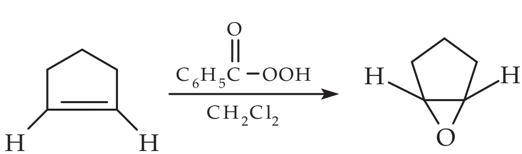
(d) None of these

187. Which of the following are correct?

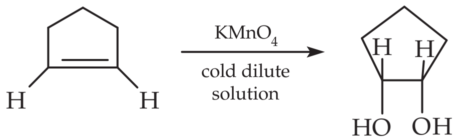
(a)



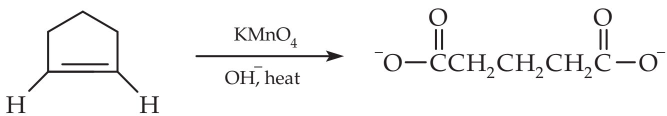
(b)



(c)



(d)



188. Which of the following reagents can be used as the basis for a simple chemical test for distinguishing 1-butene from $CH_3CH_2CH_2CH_2OH$?

(a) Br_2/CCl_4
(b) Dilute aqueous $KMnO_4$
(c) CrO_3/aqueous H_2SO_4
(d) None of these

189. Addition polymerization can be brought about by

(a) free radicals
(b) anions
(c) cations
(d) none of these

190. Which of the following can be used for the preparation of propane?

(a) $CH_3CH{=}CH_2 \xrightarrow[\text{2. } CH_3COOH]{\text{1. } B_2H_6}$

(b) $CH_3CH_2CH_2Cl \xrightarrow[\text{2. } H_2O]{\text{1. Mg/ether}}$

(c) $CH_3CH_2CH_2I \xrightarrow{\text{HI}/\Delta\ /150°C}$

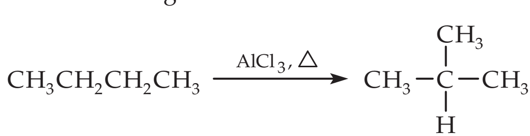
(d) $CH_3CH_2CH_2COONa \xrightarrow[\Delta]{\text{NaOH(CuO)}}$

191. The cis hydroxylation of alkenes can be effected by

(a) the addition of a 1% $KMnO_4$ solution
(b) reaction with osmium tetraoxide followed by treatment with water
(c) the addition of ozone to the alkene, followed by treatment of the ozonide with H_2O_2
(d) none of these

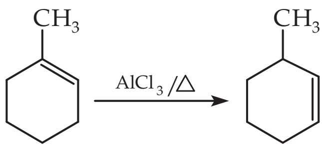
192. Which of the following transformations are feasible?

(a)

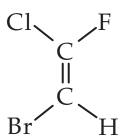


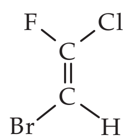
(b) $CH_3—CH_2—CH_2—CH{=}CH_2 \xrightarrow[200–300°C]{AlCl_3} CH_3—CH_2—CH{=}CH—CH_3$

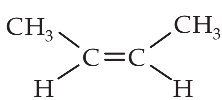
(c) $CH_3CH_2CH{=}CH_2 \xrightarrow{AlCl_3} CH_2{=}\underset{\underset{\displaystyle CH_3}{|}}{C}—CH_3$

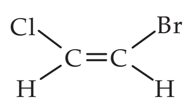
(d) 

193. Which of the following olefines have Z-configurations [in the (E)–(Z) system]?

(a) 

(b) 

(c) 

(d) 

194. What are the possible intermediates in the following reaction?

$$CH_3CH_2CH{=}CH_2 \xrightarrow[2.\ NaNH_2(110–160°C)]{1.\ Br_2/CCl_4} CH_3CH_2C{\equiv}CH$$

(a) $CH_3CH_2\underset{\underset{\displaystyle Br}{|}}{C}H—CH_2Br$

(b) $CH_3CH_2CH{=}CHBr$

(c) $CH_3CH_2\underset{\underset{\displaystyle Br}{|}}{C}{=}CH_2$

(d) None of these

195. On oxidation, an unknown alkene C_8H_{16} gives a mixture of propanoic acid (CH_3CH_2COOH) and pentanoic acid ($CH_3CH_2CH_2CH_2COOH$). The unknown alkene can be

(a) *cis*-3-octene

(b) *trans*-3-octene

(c) *cis*-4-octene

(d) *trans*-4-octene

196. The nitration of propane with concentrated HNO_3 gives

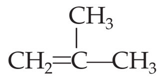
(a) $CH_3CH_2CH_2NO_2$

(b) $CH_3\underset{\underset{\displaystyle NO_2}{|}}{C}HCH_3$

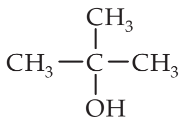
(d) $CH_3CH_2NO_2$

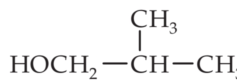
(d) CH_3NO_2

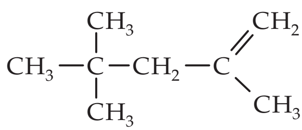
197. The reaction of isobutylene

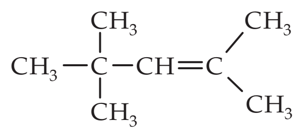


with 60% H_2SO_4 at 70°C gives

(a) 

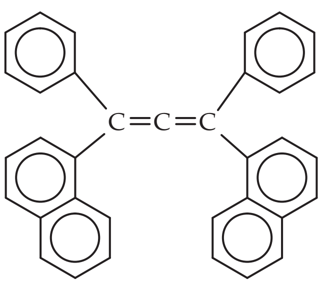
(b) 

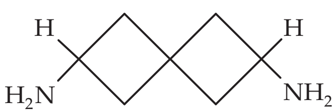
(c) 

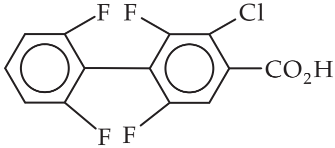
(d) 

198. Which of the following are optically active?

(a) $H_2C=C=CH_2$

(b) 

(c) 

(d) 

199. In which of the following compounds are all the carbon atoms in the sp^3 state of hybridization?

(a) CH_4 (b) C_2H_6 (c) C_3H_8 (d) C_4H_{10}

200. Which of the following statements are not correct for alkanes?

(a) All C—H and C—C bonds have a length of 1.112 Å and 1.54 Å respectively.

(b) All bond angles are tetrahedral, having a value of 109.5°.

(c) The C—C chain is linear and not zigzag.

(d) All alkanes exhibit isomerism.

201. Arrange the following in order of increase/decrease in boiling point.

$$\underset{\text{I}}{CH_3CH_2CH_2CH_2CH_3} \qquad \underset{\text{II}}{(CH_3)_2CHCH_2CH_3} \qquad \underset{\text{III}}{(CH_3)_4C}$$

(a) I > II > III (b) II > I > III

(c) III > I > II (d) III < II < I

202. Which of the following reactions can be used to prepare methane?

(a) Clemmensen reduction

(b) Wurtz reaction

(c) Catalytic hydrogenation of methyl iodide

(d) Reduction of methyl iodide by using a zinc-copper couple

203. A mixture of ethyl iodide and methyl iodide is subjected to the Wurtz reaction. The products formed are

(a) ethane (b) butane

(c) propane (d) 2-methylpropane

204. Methane is obtained when

(a) sodium acetate is heated with soda lime

(b) iodomethane is reduced

(c) aluminium carbide reacts with water

(d) potassium acetate is electrolysed

205. Which of the following will give three monobromo derivatives?

(a) $CH_3CH_2CH_2CH_2CH_2CH_3$ (b) $CH_3CH_2CH_2—CH(CH_3)CH_3$

(c) $CH_3—CH_2—C(CH_3)_2CH_3$ (d) $CH_3CH(CH_3)CH(CH_3)CH_3$

206. Which of the following compounds cannot be prepared by the Wurtz reaction?

(a) CH_3CH_3 (b) $\begin{array}{l} CH_3CH—CH_3 \\ \quad\;\; | \\ \quad\; CH_3 \end{array}$

(c) $(CH_3)_2CHCH_3$ (d) $CH_3CH_2CH_2CH_3$

207. Which of the following are cumulative dienes?

(a) $CH_3—CH{=}C{=}CH—CH_3$ (b) $CH_2{=}CH—CH{=}CH_2$

(c) $CH_2{=}CH—CH_2CH{=}CH_2$ (d) $CH_3CH_2CH{=}C{=}CH—CH_3$

208. Alkenes undergo
(a) substitution reactions (b) addition reactions
(c) ozonolysis (d) none of these

209. What are the products obtained by the ozonolysis of $RCH{=}CR_1R_2$?
(a) $RCHO$ (b) R_1R_2CO
(c) R_2CO (d) $RCH_2CH_2R_1$

210. What are the products obtained upon the ozonolysis of 2-pentene?
(a) CH_3CH_2CHO (b) CH_3CHO
(c) CH_3COCH_3 (d) $CH_3COCH_2CH_3$

211. Which of the following statements are correct for geometrical isomers?
(a) The cis-isomer is more polar than the trans-isomer.
(b) The boiling point of the cis-isomer is higher than that of the trans-isomer.
(c) Geometrical isomers have different physical properties but their chemical properties, though similar, are not identical.
(d) The stability of trans-isomers is greater than that of cis-isomers.

212. C_4H_6 may contain
(a) only single bonds (b) a double bond
(c) a triple bond (d) two double bonds

213. The reactivities of ethane, ethylene and acetylene are of the order
(a) ethane < ethylene < acetylene
(b) ethane < acetylene < ethylene
(c) acetylene > ethylene > ethane
(d) acetylene = ethylene > ethane

214. Which of the following contains acidic hydrogen?
(a) Ethene (b) Ethane
(c) Ethyne (d) Butyne-1

215. Which of the following will react with sodium metal?
(a) Ethyne (b) Butyne-1
(c) Butyne-2 (d) Ethane

216. Which of the following statements are correct?
(a) Acetylene is more reactive than ethylene to an electrophilic attack.
(b) Acetylene and ethylene show similar reactivities towards an electrophilic attack.
(c) The reactivities of acetylene and ethylene towards an electrophilic attack depend on the electrophilic reagent.
(d) Acetylene is less reactive than ethylene to an electrophilic attack.

217. Which of the following reactions will give an alkyne?

(a) Potassium fumarate $\xrightarrow{\text{electrolysis}}$

(b) $CH_3CBr_2CHBr_2 \xrightarrow{\text{Zn/alcohol}}$

(c) $CH_3CH_2CHBr_2 \xrightarrow{\text{alc. KOH}}$

(d) $CH_3CHBrCH_2Br \xrightarrow{NaNH_2}$

218. That acetylene is a linear molecule is shown by

(a) its C≡C bond distance being 1.21 Å

(b) its C—H bond distance being 1.08 Å

(c) its H—C—C bond angle being 180°

(d) X-ray diffraction

219. Which of the following react with Cl_2 and Br_2 at room temperature and in the absence of diffused sunlight to produce dihalogen derivatives?

(a) Cyclopropane (b) Cyclobutane

(c) Cyclopentane (d) Cyclohexane

220. The C=C bond distance in an organic compound is 1.34 Å. It can be

(a) butene-1 (b) butene-2

(c) cyclohexatriene (d) hexatriene

221. The product obtained in the reaction

$$C_6H_5CH_2\text{—}CH_3 \xrightarrow[273\text{ K}]{Cl_2,\ h\nu}$$

is

(a) $C_6H_5CHCl\text{—}CH_3$ (b) $C_6H_5CH_2CH_2Cl$

(c) $C_6H_5CCl_2\text{—}CH_3$ (d) $C_6H_5CHClCH_2Cl$

222. Which of the following compounds will exhibit geometrical isomerism?

(a) Butene-1 (b) Butene-2

(c) Oxime of benzaldehyde (d) Oxime of acetone

223. Which of the following will have dipole moment?

(a) Propylene (b) 1-Butene

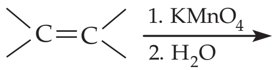
(c) *cis*-2-Butene (d) *trans*-2-Butene

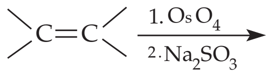
224. Which of the following is a nucleophile?

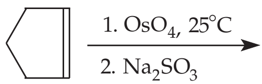
(a) $\overset{+}{N}O$ (b) $\bar{O}H$

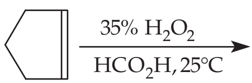
(c) $RCO\bar{O}$ (d) RNH_2

225. Which of the following will give *cis*-diols?

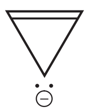
(a) 

(b) 

(c) 

(d) 

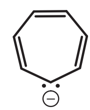
226. Which of the following structures



I

II

III



IV

will have 4 electrons?

(a) I (b) II (c) III (d) IV

227. Which of the following is a nucleophile?

(a) $:\overline{OH}$ (b) $:\overline{CN}$ (c) $:\overline{C}\equiv CR$ (d) $:\overline{SH}$

Answers

1. c	**2.** a	**3.** b	**4.** c	**5.** c
6. d	**7.** a	**8.** a	**9.** d	**10.** b
11. b	**12.** d	**13.** d	**14.** c	**15.** a
16. b	**17.** c	**18.** d	**19.** b	**20.** d
21. c	**22.** c	**23.** a	**24.** d	**25.** c
26. c	**27.** c	**28.** b	**29.** c	**30.** b
31. a	**32.** d	**33.** c	**34.** d	**35.** a
36. c	**37.** a	**38.** a	**39.** b	**40.** c
41. b	**42.** c	**43.** d	**44.** a	**45.** a
46. b	**47.** a	**48.** a	**49.** a	**50.** a
51. b	**52.** b	**53.** d	**54.** a	**55.** c
56. c	**57.** b	**58.** c	**59.** b	**60.** c
61. d	**62.** c	**63.** d	**64.** c	**65.** c
66. d	**67.** a	**68.** a	**69.** d	**70.** b

71. c	**72.** b	**73.** c	**74.** a	**75.** b
76. d	**77.** d	**78.** d	**79.** a	**80.** a
81. b	**82.** c	**83.** a	**84.** c	**85.** b
86. c	**87.** c	**88.** c	**89.** b	**90.** b
91. b	**92.** b	**93.** b	**94.** c	**95.** a
96. c	**97.** b	**98.** a	**99.** a	**100.** a
101. b	**102.** c	**103.** a	**104.** c	**105.** c
106. b	**107.** d	**108.** d	**109.** c	**110.** b
111. a	**112.** c	**113.** a	**114.** c	**115.** b
116. d	**117.** c	**118.** d	**119.** a	**120.** a
121. a	**122.** c	**123.** a	**124.** b	**125.** b
126. a	**127.** a	**128.** b	**129.** c	**130.** d
131. d	**132.** d	**133.** c	**134.** b	**135.** a
136. a	**137.** b	**138.** d	**139.** a	**140.** c
141. e	**142.** d	**143.** c	**144.** a	**145.** a
146. a	**147.** a	**148.** d	**149.** a	**150.** c
151. a	**152.** b	**153.** a	**154.** b	**155.** c
156. d	**157.** a	**158.** b	**159.** a	**160.** b
161. b	**162.** c	**163.** a	**164.** a	**165.** a
166. d	**167.** a	**168.** b	**169.** a	**170.** a
171. a, b, c	**172.** b, d	**173.** a, c	**174.** a, c	**175.** a, b, d
176. b, c, d	**177.** a, b, c, d	**178.** a, c	**179.** a, d	**180.** a, b, d
181. a, c	**182.** a, c	**183.** a, b	**184.** a, b	**185.** a, c
186. b, c	**187.** a, b, c, d	**188.** a, b, c	**189.** a, b, c	**190.** a, b, c, d
191. a, b	**192.** a, b, c	**193.** a, c, d	**194.** a, b, c	**195.** a, b
196. a, b, c, d	**197.** c, d	**198.** b, c	**199.** a, b, c, d	**200.** c, d
201. a, d	**202.** c, d	**203.** a, b, c	**204.** a, b, c	**205.** a, c
206. b, c	**207.** a, d	**208.** a, b, c	**209.** a, b	**210. a, b**
211. a, b, c, d	**212.** c, d	**213.** a, c	**214.** c, d	**215.** a, b
216. a, b, c	**217.** a, b, c, d	**218.** c, d	**219.** a, b	**220.** a, b
221. a, c	**222.** b, c	**223.** a, b, c	**224.** b, c, d	**225.** a, b, c
226. a, b, c	**227.** a, b, c, d			

Hints to More Difficult Problems

6. The potential energy of the molecules is at a minimum for the staggered conformations, increases with rotation and reaches a maximum at the eclipsed conformation.

9. Cyclohexane is virtually strain-free. Hence the heat of combustion per CH_2 is the same as for *n*-alkanes (157.4 kcal). The increase in heat of combustion for the smaller rings is due to increase in angle strain.

13. Trans elimination is easier than cis elimination. Also, the formation of a more substituted alkane is favoured.

15. Enantiomers are mirror images of each other.

19. Compounds in which the double bonds are in alternate positions, i.e., in case of conjugation, are stable.

20. Allylic hydrogen has a low bond dissociation energy, and so NBS is used as a brominating agent in the allylic position.

22. The generated dichlorocarbene adds on to the double bond.

23. The chair form of cyclohexane is not only free of angle strain, but of torsional strain as well. It is, therefore, the most stable conformation of cyclohexane.

35. The pairs which are nonsuperimposable mirror images represent enantiomers.

41. Carbon radicals in suitable unsaturated systems are more stable than alkyl radicals due to the delocalization of the unpaired electron.

44. An sp^3-sp^3 sigma bond is the longest and there is a steady decrease in the length of carbon-carbon single bonds as the hybridization state of the bonded atoms changes from sp^3 to sp.

129. To be able to react with ammoniacal $AgNO_3$, the alkyne must have an acidic (terminal) H atom.

171. Alkenes with the formula baC=Cab or baC=Ced exhibit geometrical isomerism. The oximes of aldehydes also exhibit geometrical isomerism because hindered rotation is possible with a carbon-nitrogen double bond.

174. Trans isomers, in general, have zero dipole moment.

180. A chiral carbon must have four different atoms or groups attached to it.

182. The rotation of biphenyls with ortho positions substituted by a bulky group (like —COOH, —NO_2) is restricted. The molecule has no elements of symmetry, i.e., it is not superimposable on its mirror image, and therefore exhibits optical isomerism. A simple allene does not exhibit optical isomerism but allenes of the type abC=C=Cab exist in two enantiomeric forms provided a and b are bulky groups.

183. The nonsuperimposable pairs are enantiomers.

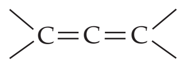
185. Alkenes with the formula baC=Cab or baC=Ced can exist as cis-trans isomers.

196. The reaction occurs by a free-radical mechanism, and so a mixture of products is obtained.

197. It is a polymerization reaction. The chain termination occurs after only one isobutylene molecule has been added. This is due to the high concentration of water; the intermediate carbonium ion loses a proton to water before it can react with another alkene molecule.

206. The Wurtz reaction is used to make alkanes with an even number of carbon atoms.

207. In cumulative dienes, there is at least one carbon atom joined to both the neighbouring carbon atoms by double bonds, i.e., they contain the group



❑

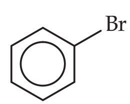
4

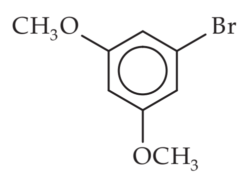
Halogen Derivatives

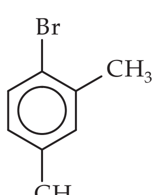
• *Type 1* •

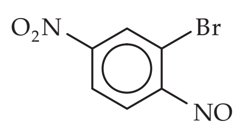
Choose the correct option. Only one option is correct.

1. Which of the following compounds is the most likely to undergo a bimolecular nucleophilic substitution reaction with aqueous NaOH?

(a) 

(b) 

(c) 

(d) 

2. Which of the following reagents can be used to distinguish chlorobenzene from chlorocyclohexane?

(a) $AgNO_3/C_2H_5OH$ (b) $Ag(NH_3)_2OH$

(c) Na fusion; HNO_3; $AgNO_3$ (d) Br_2/CCl_4

3. Which of the following can be used to prepare 3-bromopropene?

(a) $CH_3CH{=}CH_2 + Br_2 \xrightarrow[30°C]{CCl_4}$

(b) $CH_3CH{=}CH_2 +$ N-bromosuccinimide $\longrightarrow$

(c) $CH_2{=}CHCH_3 + PBr_3 \longrightarrow$

(d) $CH_2{=}CHCH_2Cl + NaBr \xrightarrow{\text{acetone}}$

4. The number of structural isomers of $C_3H_5Cl_3$ is

(a) two (b) three

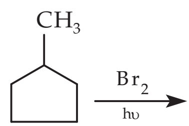
(c) four (d) five

5. Which of the following molecules has zero dipole moment?

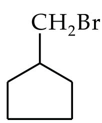
(a) CCl_4 (b) $CHCl_3$

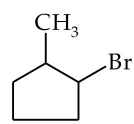
(c) CH_2Cl_2 (d) CH_3Cl

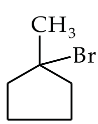
6. The major product obtained in the reaction

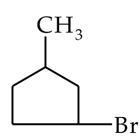


is

(a) 

(b) 

(c) 

(d) 

7. How many monochloro derivatives does the free-radical chlorination of 2,3-dimethylbutane yield?

(a) One (b) Two

(c) Three (d) Four

8. Which of the following yields one monosubstituted chloroalkane upon chlorination?

(a) Isobutane (b) Cyclopentane

(c) *n*-Butane (d) Propane

9. Which of the following alkyl halides will you expect to give the highest yield of substitution products under conditions favourable to a bimolecular reaction?

(a) $CH_3CH_2CH_2CH_2CH_2Br$ (b) $CH_3CH_2CH_2\underset{\underset{Br}{|}}{CH}{-}CH_3$

(c) $CH_3CH_2-\underset{CH_3}{\underset{|}{CH}}-CH_2Br$ (d) $CH_3CH_2-\overset{Br}{\overset{|}{\underset{CH_3}{\underset{|}{C}}}}-CH_3$

10. What is the major product in the following reaction?

$$CH_3-CH_2-\overset{CH_3}{\overset{|}{\underset{CH_3}{\underset{|}{C}}}}-Br + KOH \xrightarrow[\text{reflux}]{\text{ethanol}}$$

(a) $CH_3-CH_2-\overset{CH_3}{\overset{|}{\underset{CH_3}{\underset{|}{C}}}}-OH$ (b) $CH_3-\overset{CH_3}{\overset{|}{\underset{CH_3}{\underset{|}{C}}}}-O-\overset{CH_3}{\overset{|}{\underset{CH_3}{\underset{|}{C}}}}-CH_2CH_3$

(c) $CH_3CH_2-\underset{CH_3}{\underset{|}{C}}=CH_2$ (d) $CH_3CH=\underset{CH_3}{\underset{|}{C}}-CH_3$

11. The major product in the reaction

$$CH_3-\underset{CH_3}{\underset{|}{CH}}-\overset{CH_3}{\overset{|}{\underset{CH_2CH_3}{\underset{|}{C}}}}-Br + CH_3CH_2\overset{-}{O}\overset{+}{N}a \xrightarrow{C_2H_5OH}$$

is

(a) $(CH_3)_2C=C(CH_3)CH_2CH_3$

(b) $(CH_3)_2CH\underset{CH_2CH_3}{\underset{|}{C}}=CH_2$

(c) $(CH_3)_2CH-\underset{CH_3}{\underset{|}{C}}=CHCH_3$

(d) $(CH_3)_2CHC(CH_3)_2-\underset{CH_2CH_3}{\underset{|}{C}}-(CH_3)CH(CH_3)_2$

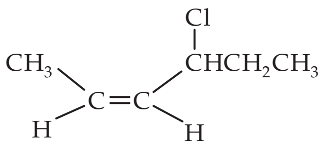
12. How many chiral stereoisomers can be drawn for $CH_3CHCl-CHBrCH_3$?

(a) Two (b) Three

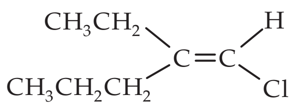
(c) Four (d) Five

13. Which of the following represents Z-3-chloro-3-heptene?

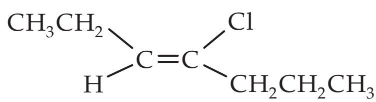
(a)



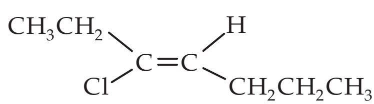
(b)



(c)



(d)



14. Which of the following is true about any R-enantiomer?

(a) It is dextrorotatory.

(b) It is levorotatory.

(c) It is an equal mixture of + and – .

(d) It is the mirror image of the S-enantiomer.

15. Which of the following is not true about enantiomers?

(a) They have the same melting or boiling point.

(b) They have the same specific rotation.

(c) They have the same density.

(d) They have the same chemical reactivity.

16. 2,2-Dichloropentane can best be synthesised by

(a) $CH_2CH_2CH_2C{\equiv}CH \xrightarrow{Cl_2}$

(b) $CH_3CH_2CH_2C{\equiv}CH \xrightarrow{H_2} [\ ] \xrightarrow{Cl_2}$

(c) $CH_3CH_2CH_2C{\equiv}CH \xrightarrow{2HCl}$

(d) $CH_3CH_2CH{=}CHCH_3 \xrightarrow{HCl}$

17. Which of the following compounds is ionic?

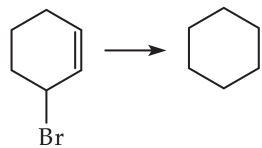
(a) BF_3

(b) CCl_4

(c) MgI_2

(d) $AlCl_3$

18. The transformation



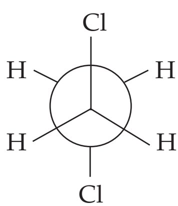
can be brought about using

(a) Zn/H^+ (b) CuI

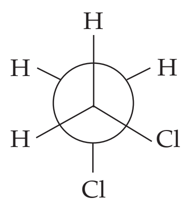
(c) Na (d) $(CH_3)_2CuLi$

19. Which of the following rotamers of 1,2-dichloroethane has zero dipole moment?

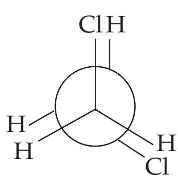
(a)



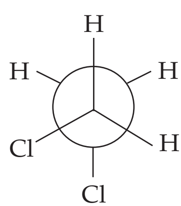
(b)



(c)



(d)



20. In the S_N2 reaction of *cis*-3-methylcyclopentyl bromide with alkali, the product formed is

(a) a cis alcohol

(b) a trans alcohol

(c) an equimolecular mixture of cis and trans alcohols

(d) there is no reaction

21. The reaction

$$RCH{=}CH{-}CH_2{-}X \xrightarrow{y^-} R{-}\underset{\displaystyle y}{\underset{|}{C}H}{-}CH{=}CH_2$$

is

(a) an S_N1 reaction (b) an S_N2 reaction

(c) an S_Ni reaction (d) none of these

22. The reaction

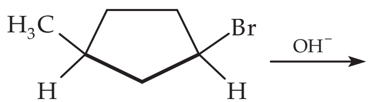
$$CH_2{=}CH{-}CH_3 + Cl_2 \xrightarrow{400°C} CH_2{=}CH{-}CH_2Cl$$

proceeds through the intermediate formation of a

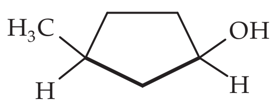
(a) free radical (b) carbocation

(c) carbanion (d) none of these

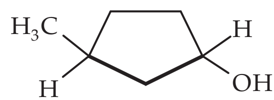
23. The product obtained in the reaction



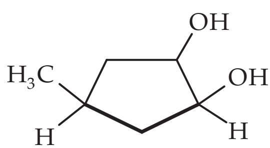
(a)



(b)



(c)



(d) none of these

24. In the reaction of optically active 2-bromo-octane with sodium hydroxide to give 2-octanol, there is

(a) retention of configuration

(b) inversion of configuration

(c) retention and inversion of configuration in equal amounts of the product

(d) no reaction

25. Which of the following alkyl halides is unreactive in an S_N2 reaction?

(a) Primary (b) Secondary

(c) Tertiary (d) Methyl chloride

26. The maximum yield of chloromethane (methyl chloride) by the chlorination of methane is obtained by

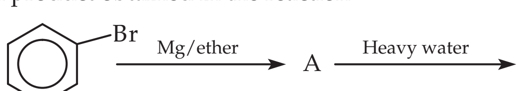
(a) using a considerable excess of methane in the reaction mixture

(b) using a large excess of chlorine in the reaction mixture

(c) using a 1 : 1 mixture of methane and chlorine

(d) carrying out the chlorination in the presence of UV light

27. The final product obtained in the reaction



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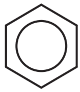
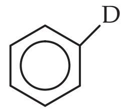
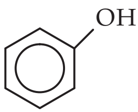
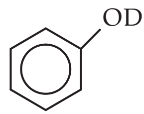
(a) 

(b) 

(c) 

(d) 

28. Which of the following is the final product in the reaction between benzoyl chloride and phenyl magnesium bromide?

(a) $$\begin{array}{c} C_6H_5 \\ | \\ C_6H_5C\text{—}OMgBr \\ | \\ Cl \end{array}$$

(b) $$\begin{array}{c} C_6H_5 \\ | \\ C_6H_5C\text{—}OH \\ | \\ Cl \end{array}$$

(c) C_6H_5COOH

(d) $(C_6H_5)_3COH$

29. The major product obtained in the reaction of propyl benzene with chlorine in the presence of UV radiation is

(a) 1-chloro-1-phenylpropane
(b) 2-chloro-1-phenylpropane
(c) 3-chloro-1-phenylpropane
(d) none of these

30. Which of the following sequence of reactions will give 1-bromo-4-trichloromethylbenzene?

(a) Toluene $\xrightarrow[Fe]{Br_2}$ *o*-bromotoluene $\xrightarrow[h\nu \text{ or heat}]{Cl_2}$

(b) Toluene $\xrightarrow[Fe]{Br_2}$ *p*-bromotoluene $\xrightarrow[h\nu \text{ or heat}]{Cl_2}$

(c) Toluene $\xrightarrow[h\nu \text{ or heat}]{Cl_2}$ trichloromethyl benzene $\xrightarrow[Fe]{Br_2}$

(d) none of these

31. The bond dissociation energy of the C—X bond in CH_3—F, CH_3—Cl and CH_2=$CHCH_2$—Cl where X is F or Cl is of the order

(a) $CH_3\text{—}F > CH_3\text{—}Cl > CH_2\text{=}CHCH_2\text{—}Cl$
(b) $CH_2\text{=}CHCH_2Cl > CH_3\text{—}Cl > CH_3\text{—}F$
(c) $CH_3\text{—}Cl > CH_3\text{—}F > CH_2\text{=}CHCH_2Cl$
(d) The C—X dissociation energy in all the compounds is of the same order.

32. The products obtained in the reaction

$$CH_2{=}CH{-}CH_2Cl + RMgX \longrightarrow$$

are

(a) $CH_2{=}CH{-}CH_2MgX$ and RCl

(b) $CH_2{=}CHCH_2R$ and $MgXCl$

(c) $CH_2{=}CH{-}CH_2{-}CH_2CH{=}CH_2$

(d) none of these

33. The halogen derivatives of alkenes are known as

(a) alkyl halides (b) alkenyl halides

(c) alkynyl halides (d) aryl halides

34. In unimolecular nucleophilic substitution, alkyl halides react via the carbocation intermediate. The order of reactivity of the carbocations is

(a) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1}$ (b) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3}$

(c) $\overset{\circ}{2} > \overset{\circ}{1} > \overset{\circ}{3}$ (d) $3° = 1° > 2°$

35. In bimolecular nucleophilic substitution, alkyl halides undergo hydrolysis through the formation of an intermediate product. The reactivity of the alkyl halides is in the order

(a) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3}$ (b) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1}$

(c) $\overset{\circ}{2} > \overset{\circ}{1} > \overset{\circ}{3}$ (d) $\overset{\circ}{3} = \overset{\circ}{1} > \overset{\circ}{2}$

36. In S_N2 reactions, the order of reactivity of the halides CH_3X, C_2H_5X, n-C_3H_7X, n-C_4H_9X is

(a) $CH_3X > C_2H_5X > n\text{-}C_3H_7X > n\text{-}C_4H_9X$

(b) $C_2H_5X > n\text{-}C_3H_7X > n\text{-}C_4H_9X > CH_3X$

(c) $C_2H_5X > n\text{-}C_3H_7X > n\text{-}C_4H_9X > CH_3X$

(d) $n\text{-}C_4H_9X > n\text{-}C_3H_7X > C_2H_5X > CH_3X$

37. In a nucleophilic substitution reaction for a given alkyl group, the order of reactivity is

(a) $R{-}I > R{-}Br > R{-}Cl > R{-}F$ (b) $R{-}F > R{-}I > R{-}Br > R{-}Cl$

(c) $R{-}Cl > R{-}Br > R{-}I > R{-}F$ (d) $R{-}F > R{-}Cl > R{-}Br > R{-}I$

38. The elimination of HX from an alkyl halide forms an alkene. The order of the elimination reactions is

(a) $\overset{\circ}{3}$ halide $>$ $\overset{\circ}{2}$ halide $>$ $\overset{\circ}{1}$ halide

(b) $\overset{\circ}{1}$ halide $>$ $\overset{\circ}{2}$ halide $>$ $\overset{\circ}{3}$ halide

(c) $\overset{\circ}{1}$ halide = $\overset{\circ}{2}$ halide > $\overset{\circ}{3}$ halide

(d) $\overset{\circ}{2}$ halide > $\overset{\circ}{1}$ halide > $\overset{\circ}{3}$ halide

39. Chlorine is the most reactive towards aqueous NaOH in
(a) methyl chloride (b) chlorobenzene
(c) vinyl chloride (d) benzyl chloride

40. Chlorine is least reactive in
(a) methyl chloride (b) ethyl chloride
(c) allyl chloride (d) vinyl chloride

41. Chlorobenzene can be prepared from aniline by making the latter react with
(a) cuprous chloride
(b) hydrochloric acid
(c) nitrous acid followed by heating with cuprous chloride
(d) chlorine in the presence of ahnydrous $AlCl_3$

42. Which of the following can function as formyl chloride in formylation?
(a) HCHO + HCl (b) CO + HCl
(c) $HCOOCH_3 + HCl$ (d) $HCONH_2 + HCl$

43. Treatment of 1-phenyl-2-chloropropane with alcoholic KOH gives mainly
(a) 3-phenylpropene (b) 1-phenylpropene
(c) 1-phenylpropan-3-ol (d) 1-phenylpropan-2-ol

44. On reaction with alcoholic KOH, 1-chlorobutane gives
(a) 1-butene (b) 2-butene
(c) 1-butanol (d) 2-butanol

45. Butyronitrile may be prepared by heating
(a) propyl alcohol with KCN (b) butyl alcohol with KCN
(c) propyl chloride with KCN (d) butyl chloride with KCN

46. Chloroform is slowly oxidized by air in the presence of light to form
(a) formyl chloride (b) trichloroacetic acid
(c) formic acid (d) phosgene

47. The halogenation of paraffins with chlorine proceeds by the free-radical chain mechanism. Among the following, which is the chain-terminating reaction?

(a) $Cl_2 \longrightarrow 2Cl^{\bullet}$

(b) $CH_3Cl + Cl^{\bullet} \longrightarrow {}^{\bullet}CH_2Cl + HCl$

(c) ${}^{\bullet}CH_3 + Cl_2 \longrightarrow CH_3Cl + Cl^{\bullet}$

(d) $Cl^{\bullet} + Cl^{\bullet} \longrightarrow Cl_2$

48. What is the type of isomerism exhibited by CH_3CHCl_2 and CH_2ClCH_2Cl?
(a) Chain (b) Functional (c) Position (d) Metamerism

49. Which of the following, on being heated with alcoholic KOH, will respond positively to the carbylamine test?
(a) Chloroform and silver powder
(b) Chloroform and aniline
(c) Methyl chloride and aniline
(d) Methyl cyanide and aniline

50. Carbon tetrachloride does not have a dipole moment due to
(a) its regular tetrahedral structure
(b) its planar structure
(c) the similar electron affinities of carbon and chlorine
(d) the similar size of the carbon and chlorine atoms

51. Arrange the following compounds in order of reactivity with alcoholic silver nitrate.
$C_6H_5CH_2CH_2Br$ (I), $C_6H_5CHBrCH_3$ (II) and $C_6H_5CH{=}CHBr$ (III)
(a) II > I > III (b) I > II > III
(c) III > II > I (d) II = I > III

52. Arrange the following compounds according to reactivity with alcoholic silver nitrate or with KCN.
$C_6H_5CH_2Br$ (I), *n*-$C_6H_{13}Br$ (II) and C_6H_5Br (III)
(a) I > II > III (b) III > II > I
(c) I > III > II (d) I = II > III

53. Arrange the following compounds according to reactivity with alcoholic $AgNO_3$.
Tert. Butyl chloride (I), sec. butyl chloride (II) and CCl_4 (III)
(a) I > II > III (b) III > II > I
(c) II > I > III (d) II = III > I

54. Arrange *m*-nitrochlorobenzene (I), 2,4-dinitrochlorobenzene (II) and *p*-nitrochlorobenzene (III) according to reactivity with sodium ethoxide.
(a) I > II > III (b) III > I > II
(c) II > III > I (d) II = III > I

55. Arrange H_2O, $\overline{O}H$, CH_3O^- and CH_3COO^- in descending order of nucleophilicity (rate of S_N2 reactivity).
(a) $H_2O > \overline{O}H > \overline{O}CH_3 > CH_3COO^-$
(b) $\overline{O}CH_3 > \overline{O}H > CH_3COO^- > H_2O$
(c) $\overline{O}H > \overline{O}CH_3 > H_2O > CH_3COO^-$
(d) $CH_3COO^- > \overline{O}CH_3 > \overline{O}H > H_2O$

56. Arrange the CH_3COO^-, $C_6H_5O^-$ and $C_6H_5SO_3^-$ anions as leaving groups in the decreasing order if the pK_a values of their conjugate acids are 4.5, 10 and 2.6 respectively.

(a) $C_6H_5SO_3^- > CH_3COO^- > C_6H_5O^-$

(b) $C_6H_5O^- > CH_3COO^- > C_6H_5SO_3^-$

(c) $CH_3COO^- > C_6H_5SO_3^- > C_6H_5O^-$

(d) $CH_3COO^- > C_6H_5SO_3^- > C_6H_5O^-$

57. Of the following, which is an S_N1 reaction?

(a) $(CH_3)_3CBr + H_2O \longrightarrow$

(b) $CH_3CH_2CH_2Cl + I^- \longrightarrow$

(c) $(CH_3)_3CBr + CN^- \longrightarrow$

(d) $CH_3CHBrCH_3 + \bar{O}H$ (alc.) $\longrightarrow$

58. In the reaction

$$C_2H_5OH + HX \xrightarrow{ZnX_2} C_2H_5X$$

the order of reactivity of HX is

(a) HBr > HI > HCl (b) HI > HBr >HCl

(c) HI >HCl > HBr (d) HCl > HBr > HI

59. Which of the following reactions is the most common among alkyl halides?

(a) Nucleophilic addition (b) Nucleophilic substitution

(c) Electrophilic addition (d) Electrophilic substitution

60. An alkyl halide can be converted into an alcohol by

(a) substitution (b) addition

(c) elimination (d) dehydrohalogenation

61. The reaction $C_2H_5Br + NaOH \longrightarrow C_2H_5OH + NaBr$ is

(a) a nucleophilic substitution (b) an electrophilic substitution

(c) both (d) neither

62. Ethyl bromide can be converted into ethyl alcohol by

(a) heating with an alcoholic solution of KOH

(b) the action of moist silver oxide

(c) heating with dilute HCl and Zn

(d) refluxing with methanol

63. The reaction of an alkyl halide with magnesium gives

(a) an alkane (b) an alkene

(c) a Grignard reagent (d) Benedict's reagent

64. In the reaction

$$RI + Mg \longrightarrow A \xrightarrow{H_2O} \text{propane}$$

the alkyl halide is

(a) methyl iodide (b) ethyl iodide
(c) ethyl bromide (d) propyl bromide

65. In the reaction $CH_3MgX + CH_3OH \longrightarrow A$, the product formed (A) is

(a) an alcohol (b) acetone
(c) ethane (d) methane

66. In the reaction

$$\text{chlorobenzene} + Mg \xrightarrow[\text{ether}]{\text{dry}} A \xrightarrow{EtOH} B$$

the product formed (B) is

(a) ethylbenzene (b) phenol
(c) benzene (d) phenylmethyl ether

67. The reaction of ethyl bromide with a lead-sodium alloy gives

(a) tetraethyl bromide (b) tetraethyl lead
(c) sodium ethoxide (d) none of these

68. The Friedel–Crafts reaction of *n*-propyl bromide with benzene in the presence of anhydrous $AlCl_3$ gives

(a) *n*-propyl benzene (b) isopropyl benzene
(c) 1,4-dipropyl benzene (d) 1,2-dipropyl benzene

69. Treatment of ammonia with excess ethyl chloride will give

(a) diethylamine
(b) ethane
(c) methylamine
(d) tetraethyl ammonium chloride

70. The mixture of two organic chlorine compounds, on treatment with sodium metal in ether solution, gives isobutane as one of the products. The reactants are

(a) methyl chloride and propyl chloride
(b) methyl chloride and ethyl chloride
(c) isopropyl chloride and ethyl chloride
(d) isopropyl chloride and methyl chloride

71. The reaction of tert. butyl bromide with sodium methoxide gives

(a) isobutane (b) tert. butylmethyl ether
(c) isobutylene (d) sodium tert. butoxide

72. In the reaction $CH_3CH_2CHBrCH_3 + (CH_3)_3COK \longrightarrow$ the main product is

(a) $CH_3CH_2\underset{\displaystyle |\atop \displaystyle OC(CH_3)_3}{C}HCH_3$ (b) $CH_3CH_2\underset{\displaystyle |\atop \displaystyle OH}{C}HCH_3$

(c) $CH_3CH_2CH{=}CH_2$ (d) $CH_3CH{=}CHCH_3$

73. Which of the following has the highest melting point?

(a) *o*-Dichlorobenzene

(b) *m*-Dichlorobenzene

(c) *p*-Dichlorobenzene

(d) All have the same melting point.

74. An organic halide, $C_2H_4Cl_2$, gives an unsaturated hydrocarbon on treatment with alcoholic KOH, but ethanal on reaction with aqueous KOH. The dihalide is

(a) CH_3CHCl_2 (b) CH_2ClCH_2Cl

(c) a mixture of (a) and (b) (d) none of these

75. Arrange the following in order of increasing ease of nucleophilic substitution reaction.

Chlorobenzene (I), 2,4,6-trinitrochlorobenzene (II),
2,4-dinitro- chlorobenzene (III) and 4-nitrochlorobenzene (IV)

(a) I < IV < III < II (b) I < III < IV < II

(c) II < III < IV < I (d) IV < III < II < I

76. The fusion of chlorobenzene with solid NaOH gives

(a) benzene (b) benzoic acid

(c) no reaction (d) phenol

77. The action of chloral on chlorobenzene gives

(a) BHC (b) DDT (c) gammexene (d) lindane

78. Benzyl alcohol on reaction with PCl_5 gives

(a) benzene (b) toluene

(c) benzyl chloride (d) none of these

79. In the reaction $C_6H_5CH_2Cl + KCN(aq.) \longrightarrow X + Y$, the compounds X and Y are

(a) C_6H_6 and KCl (b) $C_6H_5CH_3$ and KCl

(c) $C_6H_5CH_2CN$ and KCl (d) none of these

80. In the reaction $C_6H_5CH_2Cl + X \longrightarrow C_6H_5CH_2NH_2 + Y$, the compounds X and Y are

(a) HNO_3 and HCl (b) NH_3 and HCl

(c) HNO_2 and H_2O (d) none of these

81. The oxidation of benzyl chloride with $Pb(NO_3)_2$ gives
(a) benzoic acid (b) benzene
(c) benzaldehyde (d) none of these

82. Treatment of ethylidene chloride with aqueous KOH gives
(a) ethylene glycol (b) acetaldehyde
(c) formaldehyde (d) none of these

83. On distillation with bleaching powder, ethyl alcohol gives
(a) acetone (b) trichloroacetone
(c) chloroform (d) acetic acid

84. Chloroform is stored in bottles in the presence of
(a) CH_3COOCH_3 (b) C_2H_5OH
(c) CH_3COOH (d) none of these

85. In the reaction $2CHCl_3 + O_2 \xrightarrow{X} 2COCl_2 + 2HCl$, X is
(a) an oxidizing agent (b) a reducing agent
(c) light and air (d) none of these

86. On being heated with aniline and KOH, chloroform gives
(a) an almond-like smell
(b) a rose-like odour
(c) a smell like oil of wintergreen
(d) an offensive smell

87. On being warmed with silver powder, chloroform gives
(a) C_6H_6 (b) C_2H_4
(c) C_2H_2 (d) CH_3Cl

88. The reaction of chloroform with concentrated HNO_3 gives
(a) $CHCl_2NO_2$ (b) $CHCl_2HNO_3$
(c) CCl_3NO_2 (d) none of these

89. Chloroprin is
(a) $C_2H_5C(NO)_5SH$ (b) CCl_3CHO
(c) CCl_3NO_2 (d) CCl_3NO_3

90. Chloropicrin is used as
(a) an anaesthetic (b) an insecticide
(c) a hypnotic drug (d) all of these

91. The final product formed upon the hydrolysis of $CHCl_3$ by aqueous KOH is
(a) HCOOH (b) HCOOK
(c) CH_3OH (d) none of these

92. The reaction of chloroform with acetone gives

(a) mesitylene (b) ethylidene chloride
(c) chloretone (d) chloral

93. Iodoform is used as an

(a) anaesthetic (b) analgesic
(c) antiseptic (d) antifebrin

94. CCl_4 is insoluble in H_2O because

(a) H_2O is polar (b) CCl_4 is nonpolar
(c) H_2O and CCl_4 are polar (d) none of these

95. Which of the following is known as freon?

(a) CCl_2F_2 (b) $CHCl_3$
(c) CH_2F_2 (d) CF_4

96. CCl_4 is used as a fire extinguisher because

(a) of its covalent bond
(b) of its low b.p.
(c) of its high m.p.
(d) it gives incombustible vapours

97. CCl_4 is used in fire extinguishers under the name

(a) pyrene (b) phosphine
(c) phosgene (d) none of these

98. The reactivities of CH_3Cl, $CH_3CH_2CH_2Cl$ and C_6H_5Cl are in the order

(a) $CH_3Cl > CH_3CH_2CH_2Cl > C_6H_5Cl$
(b) $CH_3CH_2CH_2Cl > CH_3Cl > C_6H_5Cl$
(c) $C_6H_5Cl > CH_3CH_2CH_2Cl > CH_3Cl$
(d) $CH_3Cl > C_6H_5Cl > CH_3CH_2CH_2Cl$

99. Aryl halides are less reactive towards nucleophilic substitution reactions than are alkyl halides. This is due to

(a) the formation of the less stable carbonium ion
(b) resonance stabilization
(c) their longer C-halogen bond
(d) the inductive effect

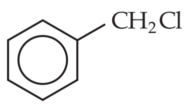
100. Of the possible structures for the molecular formula $C_5H_{11}Br$, how many are optically active?

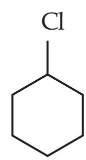
(a) One (b) Three
(c) Five (d) Four

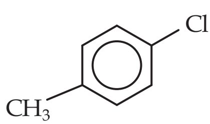
101. Of the three isomeric dihaloarenes *o*-, *m*- and *p*-, which has the highest m.p.?

(a) *o*-
(b) *m*-
(c) *p*-
(d) They have the same m.p.

102. Which of the following will be the least reactive towards nucleophilic substitution?

(a) 

(b) 

(c) 

(d) C_2H_5Cl

103. For a given alkyl group, the boiling points of alkyl halides follow the order

(a) RCl > RBr > RI
(b) RI > RBr > RCl
(c) RI > RCl > RBr
(d) RBr > RI > RCl

104. In the reaction

$$CH_3CHCl_2 \xrightarrow{\text{aq. KOH}} X$$

X is

(a) CH_3CH_2OH
(b) $(CH_3)_2CO$
(c) $\underset{\displaystyle OH}{\underset{|}{CH_2}}—\underset{\displaystyle OH}{\underset{|}{CH_2}}$
(d) CH_3CHO

105. The trade name of trichloroethylene is

(a) Freon
(b) Westron
(c) Westrosol
(d) DDT

106. Chlorobenzene can be obtained from benzene diazonium chloride by the

(a) Friedel–Crafts reaction
(b) Gattermann reaction
(c) Wurtz reaction
(d) Fittig reaction

107. The main product of the reaction $(CH_3)_3CCl \xrightarrow{\text{aq. KOH}}$ is

(a) $CH_3—CH{=}CH—CH_3$

(b) $CH_3—\underset{\displaystyle CH_3}{\underset{|}{C}}{=}CHOH$

(c) $CH_3—\overset{\displaystyle CH_3}{\overset{|}{C}}{=}CH_2$

(d) $(CH_3)_3COH$

108. Chlorination of toluene in the presence of light and heat followed by treatment with aqueous NaOH gives

(a) *o*-cresol (b) *p*-cresol

(c) 2,4-dihydroxytoluene (d) benzoic acid

109. Which of the following can give only two monochloro derivatives?

(a) *n*-Hexane (b) 2,4-Dimethylpentane

(c) 2-Methylpropane (d) Benzene

110. In the reaction

$$CH_3CH_2I \xrightarrow{\text{alc. KOH}} X \xrightarrow{Br_2} Y \xrightarrow{KCN} Z$$

Z is

(a) CH_3CH_2CN (b) CH_2BrCH_2CN

(c) $CNCH_2CH_2CN$ (d) $BrCH{=}CHCN$

111. In the reaction

$$CH_3\underset{\displaystyle Br}{\underset{|}{C}}HCH_3 \xrightarrow{\text{alc. KOH}} A \xrightarrow[\text{peroxide}]{HBr} B \xrightarrow[\text{acetone}]{NaI} C$$

C is

(a) $CH_3CH_2CH_2I$

(b) $CH_3—\underset{\displaystyle I}{\underset{|}{C}}H—CH_3$

(c) $CH_3—\underset{\displaystyle I}{\underset{|}{C}}H—CH_2I$

(d) $CH_3CH{=}CHI$

112. Which of the following will react according to S_N2 as well as S_N1 mechanisms?

(a) CH_3CH_2Cl (b) $(CH_3)_2CHCl$

(c) $(CH_3)_3CCl$ (d) $CH_3CH_2CH_2Cl$

113. What is the order of the ease of formation of the following carbocations?

(a) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1} > \overset{+}{C}H_3$ (b) $\overset{+}{C}H_3 > \overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3}$

(c) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3} > \overset{+}{C}H_3$ (d) $\overset{+}{C}H_3 > \overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1}$

114. How many optically active isomers are possible for compounds with the molecular formula $C_5H_{11}Br$?

(a) Two (b) Three (c) Four (d) Five

115. The fission of the bond in a compound A—B to give the intermediate $\bar{A}:$ and B^+ may be attributed to

(a) homolytic bond fission
(b) heterolytic bond fission
(c) homolytic as well as heterolytic bond fission
(d) none of these

116. Arrange the following in decreasing order of C-halogen bond length.

(a) $CH_3I > CH_3Br > CH_3Cl > CH_3F$

(b) $CH_3F > CH_3Br > CH_3I > CH_3Cl$

(c) $CH_3Cl > CH_3Br > CH_3I > CH_3F$

(d) $CH_3I > CH_3Cl > CH_3Br > CH_3F$

117. The reaction $CH_3MgBr + CH_3C{\equiv}CH \longrightarrow$ will give

(a) methane (b) ethane
(c) propane (d) isopropane

118. The +I effect of the following groups

CH_3—	CH_3CH_2—	$(CH_3)_2CH$—	$(CH_3)_3C$—
I	II	III	IV

decreases in the order

(a) I > II > III > IV (b) IV > III > II > I
(c) I > IV > III > II (d) II > I > III > IV

119. The ease of dehydrohalogenation with alcoholic KOH in case of chloroethane (I), 2-chloropropane (II) and 2-chloro-2-methylpropane (III) is of the order

(a) III > II > I (b) I > II > III
(c) II > I > III (d) I > III > II

120. Which of the following are nucleophilic addition reactions ?

(a) $(CH_3)_2C{=}O + HCN \longrightarrow$

(b) $CH_3CH{=}CH_2 + HBr \longrightarrow$

(c) $CH_3CH{=}CH_2 + HBr \xrightarrow{\text{peroxide}}$

(d) $CH_3CONH_2 \xrightarrow{Br_2/KOH}$

121. How many isomers are possible for compounds having the molecular formula $C_5H_{11}Br$?

(a) Five (b) Six (c) Seven (d) Eight

122. The boiling points of the haloalkanes CH_3I, CH_3Br, CH_3Cl and CH_3F decrease in the order

(a) $CH_3I > CH_3Br > CH_3Cl > CH_3F$
(b) $CH_3F > CH_3Cl > CH_3Br > CH_3I$
(c) $CH_3Br > CH_3Cl > CH_3F > CH_3I$
(d) The boiling points of haloalkanes follow no particular order.

123. The boiling points of methyl bromide (I), ethyl bromide (II), *n*-propyl bromide (III) and *n*-butyl bromide (IV) decrease in the order

(a) I > II > III > IV (b) IV > III > II > I
(c) I > III > II > IV (d) III > IV > I > II

124. The stabilities of alkyl fluorides (I), alkyl chlorides (II), alkyl bromides (III) and alkyl iodides (IV) decrease in the order

(a) I > II > III > IV (b) IV > III > II > I
(c) I > IV > II > III (d) II > I > IV > III

125. The strengths of carbon-halogen bonds follow the order

(a) R—F > R—Cl > R—Br > R—I
(b) R—I > R—Br > R—Cl > R—F
(c) R—F > R—I > R—Br > R—Cl
(d) R—Cl > R—Br > R—I > R—F

126. In the elimination reactions, the reactivities of alkyl halides follow the order

(a) R—F > R—Cl > R—Br > R—I (b) R—Cl > R—Br > R—I > R—F
(c) R—I > R—Br > R—Cl > R—F (d) R—Br > R—I > R—Cl > R—F

127. The stabilites of alkenes follow the order

(a) $R_2C{=}CH_2 > R_2C{=}CHR > RCH{=}CHR > CH_2{=}CH_2$
(b) $R_2C{=}CH_2 > CH_2{=}CH_2 > R_2C{=}CHR > RCH{=}CHR$
(c) $CH_2{=}CH_2 > RCH{=}CHR > R_2C{=}CHR > R_2C{=}CH_2$
(d) All alkenes are equally stable.

128. In the reaction

$$R{-}Br + Cl^- \xrightarrow{\text{dimethyl formamide}} R{-}Cl + Br^-$$

the relative rates of reaction of methyl bromide (I), ethyl bromide (II), isopropyl bromide (III) and tert. butyl bromide (IV) follow the order

(a) I > II > III > IV (b) IV > III > II > I
(c) IV > I > II > III (d) II > III > IV > I

129. In the reaction

$$R—Br + Cl^- \longrightarrow R—Cl + Br^-$$

the rates of reaction of ethyl bromide (I), *n*-propyl bromide (II), isobutyl bromide (III) and neopentyl bromide (IV) follow the order

(a) IV > III > II > I (b) I > II > III > IV

(c) I > III > II > IV (d) III > II > IV > I

130. The amounts of energy needed to form the carbocations $\overset{+}{C}H_3$, $\overset{\circ}{1}$, $\overset{\circ}{2}$ and $\overset{\circ}{3}$ follow the order

(a) $\overset{+}{C}H_3 > \overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3}$ (b) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1} > \overset{+}{C}H_3$

(c) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3} > \overset{+}{C}H_3$ (d) $\overset{\circ}{2} > \overset{\circ}{3} > \overset{\circ}{1} > \overset{+}{C}H_3$

• Type 2 •

Choose the correct options. More than one option is correct.

131. 2-phenyl-2-hexanol can be prepared by Grignard synthesis. Which of the following pair of compounds can one start with?

(a) $CH_3CH_2CH_2CH_2Br$ and $CH_3—\overset{\overset{O}{\|}}{C}—C_6H_5$

(b) $CH_3\underset{\underset{CH_3}{|}}{CH}—CH_2Br$ and $\overset{\overset{O}{\|}}{\underset{\underset{CH_3}{|}}{C}}—C_6H_5$

(c) $CH_3CH_2CH_2CH_2—\overset{\overset{O}{\|}}{C}C_6H_5$ and C_6H_5Br

(d) None of these

132. Which of the following reagents can be used to distinguish $CH_2{=}CHCH_2Cl$ from $CH_3CH_2CH_2Cl$?

(a) Na fusion; HNO_3, $AgNO_3$ (b) $Ag(NH_3)_2OH$

(c) $AgNO_3/C_2H_5OH$ (d) Br_2/CCl_4

133. In the reaction

$$R—COOAg + Br_2 \longrightarrow RBr + CO_2 + AgBr$$

the reaction proceeds through the intermediate formation of

(a) $R—\overset{\overset{O}{\|}}{C}—O—Br$ (b) $R—\overset{\overset{O}{\|}}{C}—O—Br^{\bullet}$

(c) $R^{\bullet}$ (d) none of these

134. Alkyl iodides can be prepared by

(a) $RCH_2COOAg + I_2 \xrightarrow[\Delta]{CCl_4} RCH_2I$

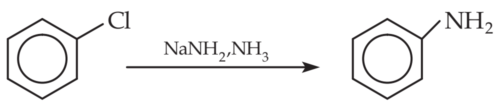
(b) $RCH_2Cl + NaI \xrightarrow[\Delta]{\text{acetone}} RCH_2I + NaCl$

(c) $R—OH + HI \longrightarrow RI + H_2O$

(d) $CH_4 + I_2 \longrightarrow CH_3I$

135. Which of the following reactions are not feasible?

(a)



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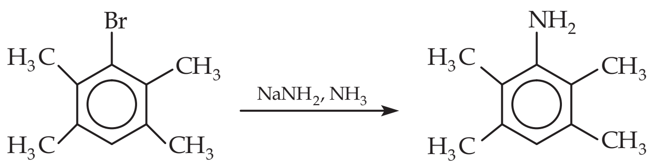

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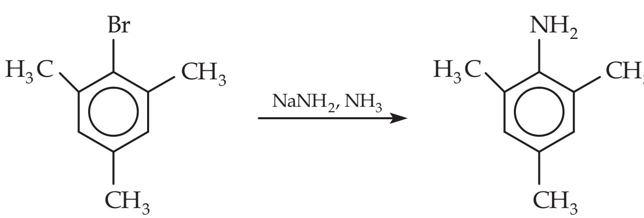
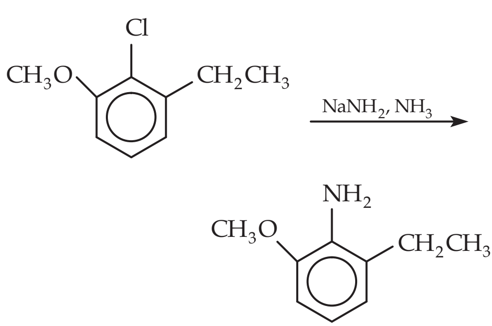


(d)



136. Which of the following are expected to have dipole moments?

(a) *cis*-1,2-dichloroethene (b) *trans*-1,2-dichloroethene

(c) *cis*-1,2-dibromoethene (d) *trans*-1,2-dibromoethene

137. Which of the following are expected to have dipole moments?

(a) Tetrachloroethene (b) Chloroform

(c) Sulphur dioxide (d) Carbon dioxide

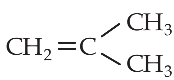
138. Which of the following are Lewis bases?

(a) $AlCl_3$ (b) H^+

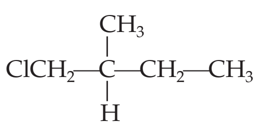
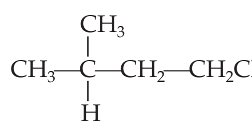
(c) Br_2 (d) R—O—H

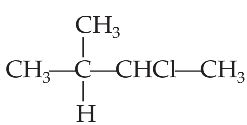
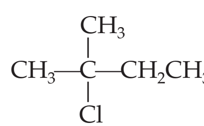
139. The treatment of tertiary butyl chloride with 80% aqueous ethanol at 25°C gives

(a) $(CH_3)_3C—OH$ (b) $(CH_3)_3C—OCH_2CH_3$

(c)  (d) none of these

140. Which monosubstituted product does the chlorination of isopentane $[(CH_3)_2CHCH_2CH_3]$ with chlorine at 300°C give?

(a)  (b) 

(c)  (d) 

141. The treatment of ethyl bromide with alcoholic silver nitrite gives

(a) ethane (b) ethene

(c) nitroethane (d) ethyl nitrite

142. Acetyl chloride does not react with

(a) ethanol (b) ethanal

(c) diethyl ether (d) propanal

143. Of the following, which are S_N2 reactions?

(a) $CH_3CH_2CH_2CI + I^- \longrightarrow$

(b) $(CH_3)_3CBr + CN^-$ (alc.) $\longrightarrow$

(c) $CH_3CHBrCH_3 + OH^-$(aq.) $\longrightarrow$

(d) $CH_3CHBrCH_3 + OH^-$ (alc.) $\longrightarrow$

144. Which of the following reagents can be used to prepare an alkyl halide from an alcohol?

(a) NaCl (b) $HCl + ZnCl_2$
(c) $SOCl_2$ (d) PCl_5

145. Aryl halides undergo

(a) the Fittig reaction (b) the Ullmann reaction
(c) the Grignard reaction (d) none of these

146. Which of the following are organometallic compounds?

(a) C_3H_7MgI (b) C_2H_5ONa
(c) $(CH_3)_3Al$ (d) TEL

147. Which of the following reactions depict the nucleophilic substitution of C_2H_5Br?

(a) $C_2H_5Br + C_2H_5SNa \longrightarrow C_2H_5SC_2H_5 + NaBr$
(b) $C_2H_5Br + 2H \longrightarrow C_2H_6 + HBr$
(c) $C_2H_5Br + AgCN \longrightarrow C_2H_5NC + AgBr$
(d) $C_2H_5Br + KOH \longrightarrow C_2H_5OH + KBr$

148. For an S_N2 reaction, which of the following statements are true?

(a) The rate of reaction is independent of the concentration of the nucleophile.
(b) The nucleophile attacks the C-atom on the side of the molecule opposite to the group being displaced.
(c) The reaction proceeds with simultaneous bond formation and rupture.
(d) None of these

149. Which of the following reactions can be used for the preparation of alkyl halides?

(a) $CH_3CH_2OH + HCl \xrightarrow{\text{anhyd. } ZnCl_2}$
(b) $CH_3CH_2OH + HCl \longrightarrow$
(c) $(CH_3)_3COH + HCl \longrightarrow$
(d) $(CH_3)_2CHOH + HCl \xrightarrow[ZnCl_2]{\text{anhy.}}$

150. Which of the following compounds, on being warmed with iodine solution and NaOH, will give iodoform?

(a) CH_3CH_2OH (b) CH_3COCH_3
(c) $\begin{matrix}H_3C\\H_3C\end{matrix}\!\!>CHOH$ (d) CH_3OH

151. Vinyl chloride undergoes

(a) addition reactions (b) elimination reactions
(c) substitution reactions (d) none of these

152. Which of these statements are true for the isomeric compounds ethylene chloride and ethylidene chloride?

(a) Both react with aqueous KOH to give the same product.
(b) Both react with alcoholic KOH to give the same product.
(c) They are derivatives of ethane.
(d) They respond to Beilstein's test.

153. The reaction of ethyl alcohol and bleaching powder gives

(a) acetaldehyde (b) chloroform
(c) chloral (d) none of these

154. Which of the following occurs during the formation of $CHCl_3$ from C_2H_5OH and bleaching powder?

(a) Oxidation (b) Reduction
(c) Hydrolysis (d) Chlorination

155. Which of the following statements are true about chloroform?

(a) It is used as an anaesthetic.
(b) It is used as a solvent.
(c) It has sp^2-hybridized carbon.
(d) It has a distorted tetrahedral shape.

156. Which of the following methods can be used for the preparation of acetylene?

(a) $CH_3CHCl_2 + \text{alc. KOH} \longrightarrow$
(b) $ClCH_2CH_2Cl + \text{alc. KOH} \longrightarrow$
(c) $ClCH_2CH_2Cl + NaNH_2 \xrightarrow[\Delta]{\text{liq. } NH_3}$
(d) None of these

157. The halogen atom in haloalkanes can be easily replaced by nucleophiles such as

(a) CN^- (b) NO_2^-
(c) OR^- (d) none of these

158. Which of the following will give vinyl chloride?

(a) $CH{\equiv}CH + HCl \xrightarrow{Hg^{2+}}$
(b) $CH_2{=}CH_2 + Cl_2 \longrightarrow \underset{\displaystyle Cl}{\underset{|}{CH_2}}{-}\underset{\displaystyle Cl}{\underset{|}{CH_2}} \xrightarrow[\text{heat}]{\text{NaOH solution}}$

(c) $CH_2{=}CH_2 + Cl_2 \xrightarrow[600°C]{}$

(d) $ClCH_2 \longrightarrow CH_2Cl \xrightarrow[\text{ethanol}]{\text{KOH}}$

159. Which of the following is an S_N2 reaction?

(a) $CH_3CH_2Br + KOH \longrightarrow CH_3CH_2OH + KBr$

(b) $CH_3CH_2Br + CH_3CH_2ONa \longrightarrow CH_3CH_2OCH_2CH_3 + NaBr$

(c) $(CH_3)_3CBr + KOH \longrightarrow (CH_3)_3COH + KBr$

(d) $CH_3{-}CH_2{-}\underset{CH_3}{\overset{CH_3}{\underset{|}{\overset{|}{C}}}}{-}Br + KOH \longrightarrow CH_3CH_2{-}\underset{CH_3}{\overset{CH_3}{\underset{|}{\overset{|}{C}}}}{-}OH + KBr$

160. Which of the following statements are correct?

(a) An S_N1 reaction proceeds with inversion of configuration.

(b) An S_N2 reaction proceeds with stereochemical inversion.

(c) An S_N2 reaction follows second-order kinetics.

(d) The reaction of tert. butyl bromide with $\bar{O}H$ follows first-order kinetics.

Answers

1. d	**2.** a	**3.** b	**4.** d	**5.** a
6. c	**7.** b	**8.** b	**9.** a	**10.** d
11. a	**12.** c	**13.** d	**14.** d	**15.** b
16. c	**17.** c	**18.** a	**19.** a	**20.** b
21. a	**22.** a	**23.** b	**24.** b	**25.** c
26. a	**27.** b	**28.** d	**29.** a	**30.** c
31. a	**32.** b	**33.** b	**34.** a	**35.** a
36. a	**37.** a	**38.** a	**39.** d	**40.** d
41. c	**42.** b	**43.** b	**44.** a	**45.** c
46. d	**47.** d	**48.** c	**49.** b	**50.** a
51. a	**52.** a	**53.** a	**54.** c	**55.** b
56. a	**57.** a	**58.** b	**59.** b	**60.** a
61. a	**62.** b	**63.** c	**64.** d	**65.** d
66. c	**67.** b	**68.** b	**69.** d	**70.** d
71. c	**72.** d	**73.** c	**74.** a	**75.** a
76. d	**77.** b	**78.** c	**79.** c	**80.** b
81. c	**82.** b	**83.** c	**84.** b	**85.** c

86. d	**87.** c	**88.** c	**89.** c	**90.** b
91. b	**92.** c	**93.** c	**94.** b	**95.** a
96. d	**97.** a	**98.** a	**99.** b	**100.** b
101. c	**102.** c	**103.** b	**104.** d	**105.** c
106. b	**107.** d	**108.** d	**109.** c	**110.** c
111. a	**112.** b	**113.** a	**114.** b	**115.** b
116. a	**117.** a	**118.** b	**119.** a	**120.** a
121. d	**122.** a	**123.** b	**124.** a	**125.** a
126. c	**127.** a	**128.** a	**129.** b	**130.** a
131. a, c	**132.** c, d	**133.** a, b, c	**134.** b, c	**135.** b, c, d
136. b, c	**137.** a, c	**138.** c, d	**139.** a, b, c	**140.** a, b, c, d
141. c, d	**142.** b, d	**143.** a, c	**144.** b, c, d	**145.** a, b, c
146. a, c, d	**147.** a, c, d	**148.** b, c	**149.** a, c, d	**150.** a, b, c
151. a, b	**152.** b, c, d	**153.** a, b, c	**154.** a, c, d	**155.** a, b, d
156. a, b, c	**157.** a, b, c	**158.** a, b, c, d	**159.** a, b	**160.** b, c, d

Hints to More Difficult Problems

1. Halogens activated by strong electron-withdrawing groups from *o*- and *p*-positions are displaced by a bimolecular nucleophilic substitution reaction.

2. Chlorocyclohexane behaves like an aliphatic halogen-substituted hydrocarbon, and can, therefore, react with alcoholic $AgNO_3$.

3. N-Bromosuccinimide is used for allylic bromination.

7. 2,3-Dimethylbutane has 18 primary hydrogens (which are all equivalent) and two tertiary hydrogens (which are equivalent), and therefore, gives only two monosubstituted derivatives.

8. Answer this question along the same lines as Q. 7.

9. The rate of substitution of alkyl halides follows the order $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3}$ for an S_N2 path. Compounds shown in options (a) and (b) are both $\overset{\circ}{1}$ alkyl halides. The compound shown in option (b), however, is less reactive due to the steric hindrance of the methyl group.

11. The course of elimination in case of alkyl halides is determined by the Saytzev rule, i.e., H is eliminated preferentially from the carbon atom that is bonded to fewer hydrogen atoms, and thus the highly substituted alkene is the major product.

32. A Grignard reagent can participate in S_N2 reactions by furnishing R^{-}**:** as a nucleophile. Such displacements with a Grignard reagent do not proceed well with alkyl halides, but only with allyl halides.

34. The transmission of the negative charge from C to a halogen (as the number of the alkyl groups increases) promotes the ionization of the halide and hence facilitates the S_N1 mechanism. So a $\overset{\circ}{3}$ halide is the most reactive and a $\overset{\circ}{1}$ halide the least.

35. For an S_N2 attack, the enhanced inductive effect of the larger number of methyl groups in a $\overset{\circ}{3}$ alkyl halide may be expected to make the carbon atom less positively polarized than in the other alkyl halides. However, steric factors are more important because an incoming $\bar{O}H$ ion will find it more difficult to attack the $\overset{\circ}{3}$ carbon atom than the $\overset{\circ}{1}$ carbon atom because the former is heavily substituted.

53. The reactivity of an alkyl halide towards alcoholic $AgNO_3$ depends on the ability of the alkyl halide to ionize.

59. See the hint to Q. 1.

68. The $\overset{\circ}{1}$ carbonium ion isomerizes to the more stable $\overset{\circ}{2}$ carbonium ion, which in turn reacts with benzene in the Friedel–Crafts reaction to give isopropyl benzene.

75. See the hint to Q. 1.

94. Nonpolar compounds are insoluble in water.

109. See the hint to Q. 7.

133. This is an example of a Hunsdiecker reaction.

135. For the formation of benzyne intermediate, it is essential that an H should be available in an ortho position to the halogen.

❑

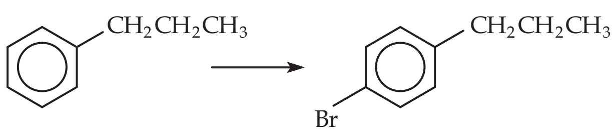
5

Aromatic Hydrocarbons or Arenes

• *Type 1* •

Choose the correct option/s. Only one option is correct.

1. The conversion



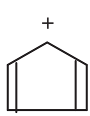
can be effected using

(a) Br_2/CCl_4 (b) Br_2/H_2O

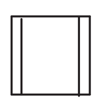
(c) Br_2/Fe (d) Br_2/benzoyl peroxide

2. Which of the following is expected to be aromatic?

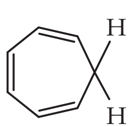
(a)



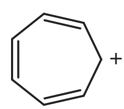
(b)



(c)



(d)



3. Why does 1,3-cyclohexadiene undergo dehydrogenation readily?

(a) It can be easily reduced.

(b) It has no resonance energy.

(c) It gains considerable stability by becoming benzene.

(d) It cannot undergo dehydrogenation.

4. How many different tetrachlorobenzenes are possible?

(a) Two (b) Three

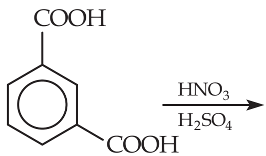
(c) Four (d) Five

5. How many isomers can tribromobenzene have?

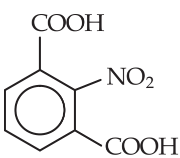
(a) One (b) Two

(c) Three (d) Four

6. The major product obtained in the reaction



is

(a)


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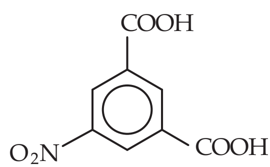

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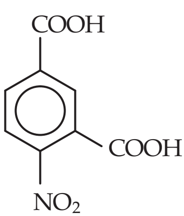

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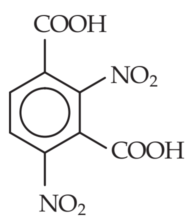
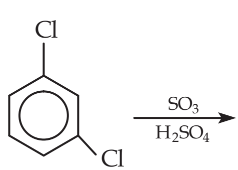


7. The major product obtained in the reaction



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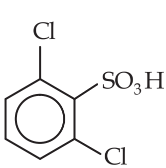
(a)


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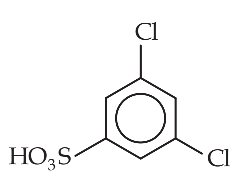

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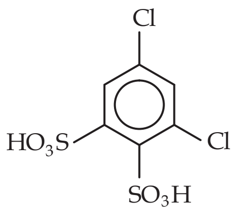
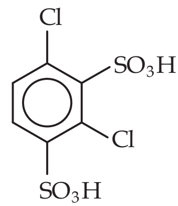
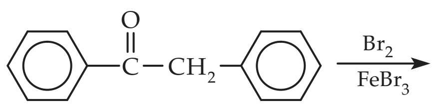


(d)

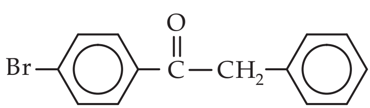


8. The major product obtained in the reaction



is expected to be

(a)



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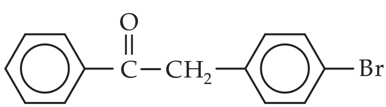

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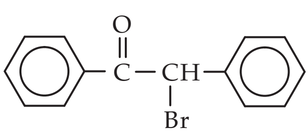
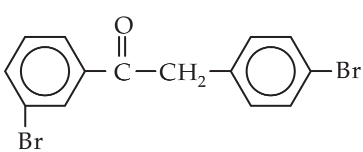


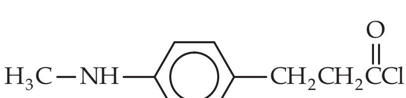
(d)

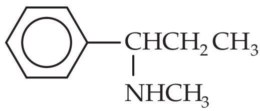


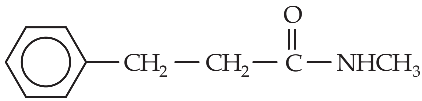
9. The final product obtained in the reaction

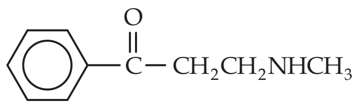
is

(a)

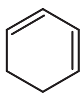


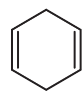
(b) 

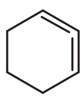
(c) 

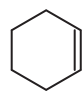
(d) 

10. Which of the following compounds is the most stable?

(a) 

(b) 

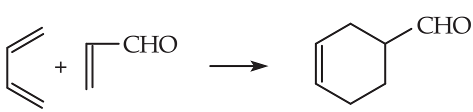
(c) 

(d) 

11. Cyclobutadiene is said to be

(a) aromatic (b) aliphatic (c) nonaromatic (d) none of these

12. The reaction



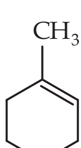
is an example of

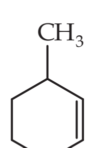
(a) [4+2] cycloaddition
(b) [2+2] cycloaddition
(c) either (4+2) or (2+2) cycloaddition
(d) none of these

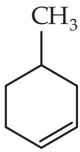
13. On oxidation with hot alkaline $KMnO_4$, an unknown alkene, C_7H_{12}, gives

$$CH_3-\overset{\overset{\displaystyle O}{\|}}{C}-CH_2CH_2CH_2CH_2\overset{\overset{\displaystyle O}{\|}}{C}-OH$$

The alkene is

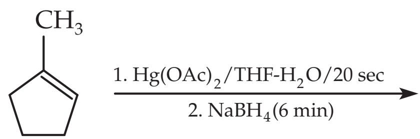
(a) 

(b) 

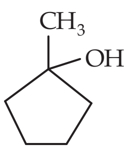
(c) 

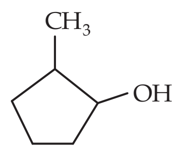
(d) none of these

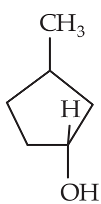
14. The final product obtained in the reaction

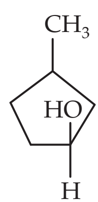


is

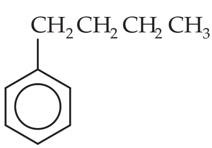
(a) 

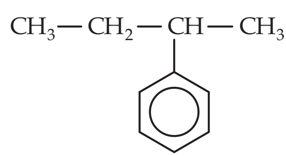
(b) 

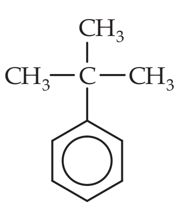
(c) 

(d) 

15. The major product obtained by the Friedel–Crafts reaction of *n*-butylbromide with benzene in the presence of anhydrous $AlCl_3$ is

(a) 

(b) 

(c) 

(d) none of these

16. The sulphonation of chlorobenzene gives exclusively

(a) an *o*-product

(b) an *m*-product

(c) a *p*-product

(d) an *o*-, *p*-disubstituted product

17. The reaction of 1-methylcyclopentene with B_2H_6 followed by treatment with alkaline H_2O_2 gives

(a) *cis*-2-methylcyclopentanol
(b) *trans*-2-methylcyclopentanol
(c) a mixture (1 : 1) of *cis*- and *trans*-2-methyl cyclopentanol
(d) none of these

18. Carbon atoms in benzene are

(a) sp-hybridized
(b) sp^2-hybridized
(b) sp^3-hybridized
(d) none of these

19. In benzene, the type of bonds are

(a) six σ and nine π
(b) six σ and six π
(c) nine σ and three π
(d) twelve σ and three π

bonds.

20. The benzene molecule contains

(a) six sp^2-hybrid carbons
(b) three sp^2-hybrid carbons
(c) six sp^3-hybrid carbons
(d) three sp^3-hybrid carbons

21. Aromatic compounds burn with a sooty flame because

(a) they have a relatively high percentage of carbon
(b) they have a ring structure
(c) they have a relatively high percentage of hydrogen
(d) they resist the action of atmospheric oxygen

22. The ozonolysis of benzene produces

(a) glyoxal
(b) ethylglyoxal
(c) dimethylglyoxal
(d) methylglyoxal

23. When an aromatic compound undergoes ozonolysis followed by treatment with H_2O/Zn, it produces glyoxal, monomethylglyoxal and dimethylglyoxal. It could be

(a) benzene
(b) toluene
(c) *o*-xylene
(d) *m*-xylene

24. How many monosubstituted products can be derived from benzene?

(a) One
(b) Two
(c) Three
(d) Four

25. All the carbon and hydrogen atoms in benzene are in a single plane and all the C—C bonds are of the same length. The C—C—C bond angle is

(a) 120°
(b) 180°
(c) 100°
(d) 109°28′

26. Which of the following statements is true for benzene?
(a) The monosubstitution of benzene produces two isomeric substances.
(b) Benzene undergoes addition reactions because of the presence of double bonds.
(c) There is a cyclic delocalization of π-electrons in benzene.
(d) There are two types of C—C bonds in the benzene molecule.

27. According to the Huckel rule, an aromatic compound has
(a) $(4n + 2)$ π-electrons (b) $(4n + 2\pi)$ electrons
(c) $(2n + 4)$ π-electrons (d) $(3n + 3\pi)$ electrons

28. The most common reactions that benzene and its derivatives undergo are
(a) electrophilic addition reactions
(b) nucleophilic addition reactions
(c) electrophilic substitution reactions
(d) nucleophilic substitution reactions

29. Which of the following are electrophilic substitution reactions?
(a) Conversion of methyl chloride to methyl alcohol
(b) Chlorination of benzene
(c) Chlorination of methane
(d) Formation of ethane from ethanol

30. The nitration of benzene by HNO_3 and H_2SO_4 is
(a) an electrophilic substitution (b) a nucleophilic substitution
(c) an electrophilic addition (d) a free-radical substitution

31. The reaction

$$C_6H_6 \longrightarrow C_6H_5CH_3$$

is a
(a) Friedel–Crafts reaction (b) Wurtz reaction
(c) Perkin reaction (d) Grignard reaction

32. In the nitration of benzene, the active nitrating agent is
(a) NO_2^- (b) NO_2^+ (c) NO_3^- (d) HNO_3

33. Which of the following represents a Friedel–Crafts reaction?

(a) $C_6H_6 + C_2H_5Cl \xrightarrow{AlCl_3} C_6H_5C_2H_5 + HCl$

(b) $C_2H_5OH + HCl \xrightarrow{ZnCl_2} C_6H_5Cl + H_2O$

(c) $C_6H_5Cl + CH_3COCl \xrightarrow{AlCl_3} C_6H_5COOCH_3 + Cl_2$

(d) $C_2H_5Br + Mg \xrightarrow{ether} C_2H_5MgBr$

34. Which of the following is the most reactive towards electrophilic nitration?

(a) Benzene (b) Toluene

(c) Benzoic acid (d) Nitrobenzene

35. Which form of xylene is most easily sulphonated?

(a) Ortho-

(b) Meta-

(c) Para-

(d) All are sulphonated at the same rate

36. Which form of xylene has only one monobromo derivative?

(a) Ortho- (b) Para-

(c) Meta- (d) None of these

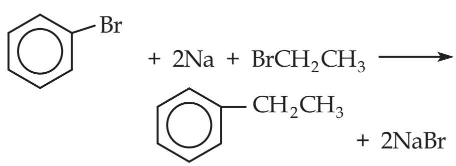
37. Arrange $C_6H_5CH_3$ (I), C_6H_6 (II), C_6H_5COOH (III), $C_6H_5NO_2$ (IV) in order of decreasing reactivity to ring monobromination.

(a) I > III > II > IV (b) III > II > IV > I

(c) I > II > III > IV (d) II > I > III > IV

38. Which of the following is a Wurtz–Fittig reaction?

(a)



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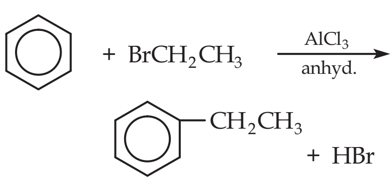

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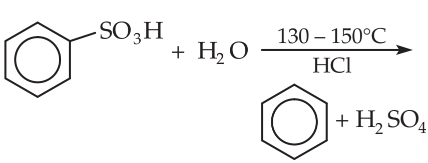

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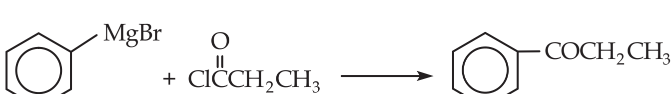
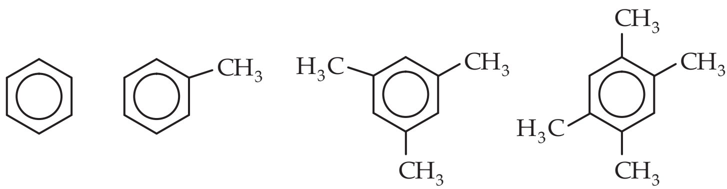


39. Arrange the following in order of decreasing boiling point.



I II III IV

(a) I > II > III > IV (b) IV > III > II > I
(c) I > III > IV > II (d) II > III > I > IV

40. The alkylation of benzene with *n*-propyl chloride in the presence of anhydrous $AlCl_3$ produces

(a) *n*-propyl benzene (b) isopropyl benzene
(c) *o*-dipropyl benzene (d) a mixture of all of these

41. Which of the following compounds does not undergo a Friedel–Crafts reaction?

(a) Benzene (b) Toluene
(c) Nitrobenzene (d) Naphthalene

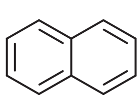
42. Toluene can be converted into benzaldehyde by oxidation with

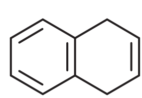
(a) $KMnO_4$/alkali (b) CrO_2Cl_2
(c) $K_2Cr_2O_7/H_2SO_4$ (d) O_2/V_2O_5

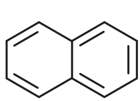
43. The heat of hydrogenation of cyclohexene is 28.6 kcal and that of cyclohexadiene is about twice as much (i.e., 55.4 kcal). What then would be the heat of hydrogenation of benzene, which has three double bonds?

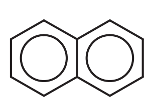
(a) Thrice that of cyclohexene (28.6×3 kcal)
(b) The same as that of cyclohexene
(c) The same as that of cyclohexadiene
(d) 49.8 kcal

44. Naphthalene is represented as

(a) 

(b) 

(c) 

(d) 

45. The directing power of the groups $—NH_2$, $—OCH_3$, $—C_6H_5$ and $—NO_2$ follows the order

(a) $—NH_2 > —OCH_3 > —C_6H_5 > —NO_2$

(b) $—NO_2 > —C_6H_5 > —OCH_3 > —NH_2$

(c) $—OCH_3 > —NH_2 > —C_6H_5 > —NO_2$

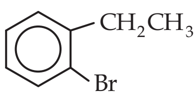
(d) $—OCH_3 > —NO_2 > —NH_2 > —C_6H_5$

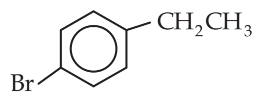
46. The reactivities of $C_6H_5CH_3$ (I), $C_6H_5CH_2Cl$ (II), $C_6H_5CHCl_2$ (III) and $C_6H_5CCl_3$ (IV) toward nitration are in the order

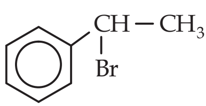
(a) I > II > III > IV (b) II > I > III > IV

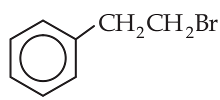
(c) IV > III > II > I (d) III > I > II > IV

47. Which of the following will be obtained by the bromination of ethylbenzene in the presence of light?

(a) 

(b) 

(c) 

(d) 

48. A Friedel–Crafts reaction of benzene with chloroform produces

(a) $C_6H_5CHCl_2$

(b) $\begin{array}{c} Cl \\ | \\ C_6H_5—C—C_6H_5 \\ | \\ H \end{array}$

(c) $\begin{array}{c} C_6H_5 \\ | \\ C_6H_5—C—C_6H_5 \\ | \\ H \end{array}$

(d) all of these

49. The stability of the free radicals allyl, benzyl, $\overset{\circ}{3}$, $\overset{\circ}{2}$, $\overset{\circ}{1}$ and $\dot{C}H_3$ is of the order

(a) allyl = benzyl > $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1} > \dot{C}H_3$

(b) allyl > benzyl > $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1} > \dot{C}H_3$

(c) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1} > \dot{C}H_3$ > allyl > benzyl

(d) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1} > \dot{C}H_3$ > allyl = benzyl

50. The reaction of $C_6H_5CH{=}CHCH_3$ with HBr produces

(a) $C_6H_5\underset{\underset{\displaystyle Br}{|}}{C}HCH_2CH_3$ (b) $C_6H_5{-}CH_2{-}\underset{\underset{\displaystyle Br}{|}}{C}H{-}CH_3$

(c) $C_6H_5CH_2CH_2CH_2Br$ (d) a mixture of these

51. Which is the major product formed in the following reaction?

$$C_6H_6 + (CH_3)_2CHCH_2OH \xrightarrow{H_2SO_4} ?$$

(a) $C_6H_5CH_2CH(CH_3)_2$ (b) $C_6H_5{-}\overset{\overset{\displaystyle CH_3}{|}}{\underset{\underset{\displaystyle CH_3}{|}}{C}}{-}CH_3$

(c) $C_6H_5{-}\overset{\overset{\displaystyle CH_3}{|}}{\underset{\underset{\displaystyle CH_3}{|}}{C}}{-}C_6H_5$ (d) A mixture of all these

52. Arrange the following compounds in order of increasing dipole moment. Toluene (I), *m*-dichlorobenzene (II), *o*-dichlorobenzene (III), *p*-di-chlorobenzene (IV)

(a) IV < I < II < III (b) I < IV < II < III

(c) IV < II < I < III (d) IV < I < III < II

53. Which of the following groups would enhance the reactivity of electrophilic aromatic substitution?

(a) $-CN$ (b) $-CHO$ (c) $-CH_3$ (d) $-NO_2$

54. Which of the following is the end product of the treatment of benzene with an excess of Cl_2 in the presence of I_2?

(a) Monochlorobenzene (b) Dichlorobenzene

(c) Trichlorobenzene (d) Hexachlorocyclohexane

55. Benzene reacts with Cl_2 in the presence of sunlight to produce

(a) C_6Cl_6 (b) C_6H_5Cl (c) $C_6H_6Cl_6$ (d) all of these

56. Benzene reacts with chlorine in the presence of iron to produce

(a) benzene hexachloride (b) benzyl chloride

(c) chlorobenzene (d) benzoyl chloride

57. Which of the following are produced when toluene is heated with chlorine in the presence of light and in the absence of a halogen carrier?

(a) $C_6H_5CH_2Cl$ (b) $C_6H_5CHCl_2$

(c) $C_6H_5CCl_3$ (d) Gammexene

58. Toluene reacts with chlorine in the presence of light to produce

(a) *o*-chlorotoluene (b) *m*-chlorotoluene
(c) *p*-chlorotoluene (d) benzyl chloride

59. The nitration of benzene with a mixture of concentrated HNO_3 and concentrated H_2SO_4 at 100°C produces

(a) nitrobenzene (b) *o*-dinitrobenzene
(c) *m*-dinitrobenzene (d) *p*-dinitrobenzene

60. The final product of the nitration of toluene is

(a) *o*-nitrotoluene (b) *m*-nitrotoluene
(c) 2,4-dinitrotoluene (d) 2,4,6-trinitrotoluene

61. The reacting species in sulphonation is

(a) SO_2 (b) SO_3
(c) SO_4^{2-} (d) H_2SO_4

62. In the Friedel–Crafts reaction of benzene with an acid chloride, the electrophilic reagent is

(a) $RCOCl^+$ (b) $R\overset{+}{C}O$
(c) $AlCl_3$ (d) none of these

63. Which of the following are produced when a mixture of benzene vapour and oxygen is passed over the catalyst V_2O_5 at 775 K?

(a) Oxalic acid (b) Glyoxal
(c) Fumaric acid (d) Maleic anhydride

64. Which of the following is the strongest *o*-, *p*-directing group?

(a) OH (b) Cl (c) Br (d) C_6H_5

65. Which of the following can be easily nitrated?

(a) Benzene (b) Phenol
(c) Nitrobenzene (d) Chlorobenzene

66. Which of the following is the least reactive in the case of bromination?

(a) Phenol (b) Aniline
(c) Nitrobenzene (d) Anisole

67. Which of the following reacts slower than benzene in electrophilic substitution?

(a) $C_6H_5CH_3$ (b) $C_6H_5NO_2$
(c) C_6H_5OH (d) $C_6H_5NH_2$

68. The nitration of toluene is a/an

(a) homolytic substitution (b) nucleophilic substitution
(c) electrophilic substitution (d) electrophilic addition

69. Which of the following is the most reactive in electrophilic substitution?
(a) Aniline (b) Nitrobenzene
(c) Aniline hydrochloride (d) Acetanilide

70. Which among (a) cyclohexane, (b) cyclopentane, (c) cyclobutane and (d) cyclopropane have a C—C—C angle of 108°?

71. How many geometrical isomers can in 1,2-dimethyl cyclohexane have?
(a) One (b) Two (c) Three (d) None of these

72. The directing power of the following groups in arenes is in the order
(a) $—NH_2 > —OCH_3 > —C_6H_5 > —CH_3$
(b) $—NH_2 > —CH_3 > —C_6H_5 > —OCH_3$
(c) $—CH_3 > —NH_2 > —OCH_3 > —C_6H_5$
(d) $—OCH_3 > —C_6H_5 > —CH_3 > —NH_2$

73. Arrange toluene (I), benzyl chloride (II), benzal chloride (III) and benzotrichloride (IV) in order of the inductive effect of the group attached to the benzene nucleus.
(a) I < II < III < IV (b) IV < III < II < I
(c) III < IV < II < I (d) II < I < III < IV

74. Arrange the following groups in order of decreasing electron-attracting capacity.
(a) $COOH > NO_2 > OH > Cl$ (b) $NO_2 > COOH > Cl > OH$
(c) $OH > Cl > COOH > NO_2$ (d) $NO_2 > COOH > OH > Cl$

75. Arrange the following groups in order of decreasing electron-donating capacity.
(a) $(CH_3)_3C— > (CH_3)_2CH— > CH_3CH_2— > CH_3—$
(b) $CH_3— > CH_3CH_2— > (CH_3)_2CH— > (CH_3)_3C—$
(c) $(CH_3)_3C— = (CH_3)_2CH— > CH_3CH_2— > CH_3—$
(d) $(CH_3)_2CH— > (CH_3)_3C— > CH_3CH_2— > CH_3—$

76. The basicities of *o*-toluidine (I), *m*-toluidine (II), *p*-toluidine (III) and aniline (IV) follow the order
(a) I > II > III > IV (b) IV > III > II > I
(c) III > II > IV > I (d) I > IV > II > III

77. The basicities of *o*-nitroaniline (I), *m*-nitroaniline (II), *p*-nitroaniline (III) and aniline (IV) follow the order
(a) I > II > III > IV (b) IV > III > II > I
(c) I > III > II > IV (d) IV > II > III > I

78. Arrange aniline (I), *N*-methylaniline (II) and *N*,*N*-dimethylaniline (III) in order of decreasing basicity.

(a) I > II > III (b) III > II > I
(c) II > I > III (d) I > III > II

79. Arrange methylamine (I), benzylamine (II) and ammonia (III) in order of basicity.

(a) II > I > III (b) III > I > II
(c) I > III > II (d) III > II > I

80. Benzenediazonium chloride, on coupling with aniline at 273–278 K in the presence of an acid (pH 4–5), gives

(a) *p*-hydroxyazobenzene (b) diazoaminobenzene
(c) *p*-aminoazobenzene (d) none of these

81. The heat of hydrogenation of one double bond in cyclohexene is 28.6 kcal mol^{-1} and the heat of hydrogenation of benzene to cyclohexane is 50 kcal mol^{-1}. What will be the resonance stabilization energy of benzene?

(a) 28.6 kcal mol^{-1} (b) 55.0 kcal mol^{-1}
(c) 85.8 kcal mol^{-1} (d) 35.8 kcal mol^{-1}

82. The reaction of benzene with chlorine in the presence of ferric chloride gives

(a) chlorobenzene (b) 2,4-dichlorobenzene
(c) 2,4,6-trichlorobenzene (d) hexachlorobenzene

83. The Friedel–Crafts reaction of benzene with propene proceeds through the formation of

(a) $CH_3CH_2\overset{+}{C}H_2$ (b) $CH_3\overset{+}{C}HCH_3$
(c) $CH_3CH_2\overset{\bullet}{C}H_2$ (d) $CH_3\overset{\bullet}{C}HCH_3$

84. Arrange the following groups in order of decreasing *o*- and *p*-directing strength.

$$—NH_2, —OH, —Cl, —R$$

(a) $—Cl > —R > —OH > —NH_2$
(b) $—NH_2 > —OH > —R > —Cl$
(c) $—OH > —NH_2 > —R > —Cl$
(d) $—R > —Cl > —NH_2 > —OH$

85. Arrange the following groups in order of decreasing *m*-directing strength.

$$—\overset{+}{N}R_3, —CN, —NO_2, —COOH$$

(a) $—\overset{+}{N}R_3 > —NO_2 > —CN > —COOH$
(b) $—COOH > —CN > —NO_2 > —\overset{+}{N}R_3$

(c) $-CN > -NO_2 > -COOH > -\overset{+}{N}R_3$

(d) $-NO_2 > -CN > -\overset{+}{N}R_3 > -COOH$

86. The nitration of isopropyl benzene exclusively gives a/an

(a) *o*-isomer (b) *m*-isomer

(c) *p*-isomer (d) 2,4-disubstituted product

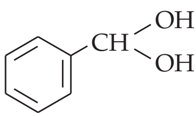
87. The reactivity of *p*-nitrochlorobenzene (I), 2,4-dinitrochlorobenzene (II) and 2,4,6-trinitrochlorobenzene (III) towards alkalis is of the order

(a) I > II > III (b) III > II > I

(c) II > I > III (d) III > I > II

88. On being heated with calcium hydroxide, benzotrichloride gives

(a)



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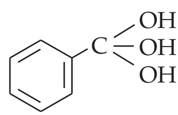

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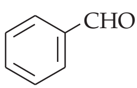
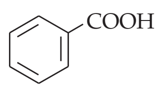


(d)



89. *m*-Dinitrobenzene can be converted into *m*-nitroaniline by reduction with

(a) Raney nickel (b) $LiAlH_4$

(c) $(NH_4)_2S$ (d) Na/C_2H_5OH

• *Type 2* •

Choose the correct options. More than one option is correct.

90. Which of the following are true?

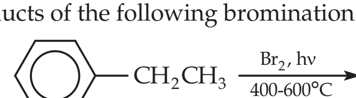
(a) Benzene tends to undergo substitution rather than addition reactions.

(b) All hydrogen atoms of benzene are equivalent.

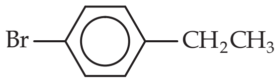
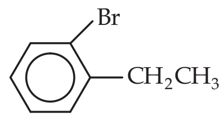
(c) The carbon-carbon bonds of benzene are alternatively short and long around the ring.

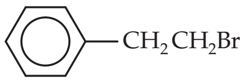
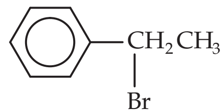
(d) There can be two *o*-disubstituted derivatives.

91. The major products of the following bromination reaction



are

(a) 
(b) 

(c) 
(d) 

92. Isopropylbenzene can be prepared by

(a) Benzene + $CH_3CH{=}CH_2 \xrightarrow[H_2SO_4]{}$

(b) Benzene + $CH_3-\underset{\underset{Cl}{|}}{CH}-CH_3 \xrightarrow[H_2SO_4]{}$

(c) Benzene + $CH_3\underset{\underset{Cl}{|}}{CH}-CH_3 \xrightarrow{AlCl_3}$

(d) Benzene + $CH_3CH_2CH_2Cl \xrightarrow{AlCl_3}$

93. Tert. butyl benzene can be prepared by

(a) Benzene + $CH_2{=}C(CH_3)_2 \xrightarrow{H_2SO_4}$

(b) Benzene + $(CH_3)_3COH \xrightarrow{H_2SO_4}$

(c) Benzene + $(CH_3)_3C-Cl \xrightarrow{AlCl_3}$

(d) none of these

94. Triphenylmethane can be prepared by

(a) Benzene + benzal chloride $\xrightarrow{AlCl_3}$

(b) Benzene + chloroform $\xrightarrow{AlCl_3}$

(c) Benzene + benzaldehyde $\xrightarrow{ZnCl_2}$

(d) none of these

95. Which of the following characteristics does an aromatic compound exhibit?

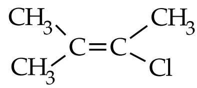
(a) It should have $(4n + 2)$ π-electrons.

(b) It should be planar and conjugated.

(c) It should have $4n$ π-electrons.

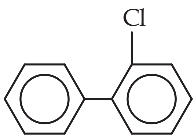
(d) It should possess high resonance energy.

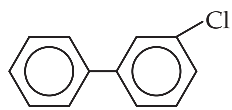
96. Which of the following do not undergo a Friedel–Crafts reaction with benzene?

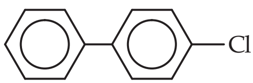
(a) Aniline
(b) Chlorobenzene
(c) 

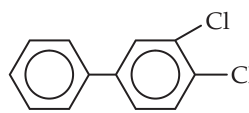
(d) Acetyl chloride

97. The reaction of biphenyl with HOCl in the presence of a strong acid gives

(a) 

(b) 

(c) 

(d) 

98. Which of the following are obtained by the fractionation of coal tar?

(a) Light oil
(b) Middle oil
(c) Heavy oil
(d) Vegetable oil

99. Which of the following statements are true for benzene?

(a) It is a flat, regular, hexagonal molecule.
(b) Each C—C—C angle is 109°28′.
(c) The C—C bond length is 1.39 Å.
(d) All carbon atoms are sp^3-hybridized.

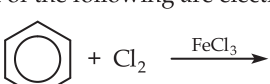
100. Which of the following meet the requirements of the Huckel rule?

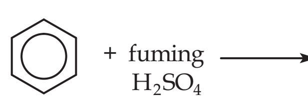
(a) Naphthalene
(b) Anthracene
(c) 1,3,5,7-Cyclooctatetraene
(d) 1,3-Cyclobutadiene

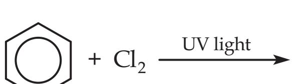
101. Which of the following compounds are aromatic?

(a) Pyridine
(b) Pyridiazine
(c) Thiophene
(d) Pyrrole

102. Which of the following are electrophilic substitution reactions?

(a) 

(b) 

(c) 

(d) All of these

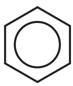
103. Toluene reacts with ethyl bromide in the presence of anhydrous $AlCl_3$ to produce

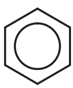
(a) *o*-ethyltoluene (b) *p*-ethyltoluene

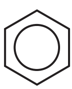
(c) *m*-ethyltoluene (d) a mixture of all of these

104. Isopropylbenzene can be obtained by

(a)  $+ CH_3—CH{=}CH_2 \xrightarrow{AlCl_3}$

(b)  $+ CH_3CH_2CH_2Cl \xrightarrow{AlCl_3}$

(c)  $+ \begin{matrix}CH_3\\CH_3\end{matrix}\!\!>CHCl \xrightarrow{AlCl_3}$

(d)  $+ CH_3CH_2OCH_3 \longrightarrow$

105. Benzene can be obtained by

(a) $C_6H_5COOH + NaOH \xrightarrow[\Delta]{CaO}$

(b) $C_6H_5OH + Zn \xrightarrow{\Delta}$

(c) $C_6H_5N{=}NCl + H_2O \longrightarrow$

(d) all of these

106. The sulphonation of toluene with oleum at 35°C produces

(a) p-toluene sulphonic acid

(b) *o*-toluene sulphonic acid

(c) *m*-toluene sulphonic acid

(d) a mixture of (a), (b) and (c) in approximately equal proportions

107. Which of the following groups are meta-directing?

(a) $—NH_2$ (b) —OH

(c) $—NO_2$ (d) —COOH

108. Which of the following groups are ortho- and para-directing?

(a) —OH (b) —CHO

(c) —CN (d) $—NHCOCH_3$

109. *m*-Nitrobenzoic acid can be obtained by

(a) toluene $\xrightarrow[KMnO_4]{[O]}$ A $\xrightarrow[H_2SO_4]{HNO_3}$

(b) toluene $\xrightarrow[CrOCl_2]{[O]}$ A $\xrightarrow[H_2SO_4]{HNO_3}$ B $\xrightarrow[KMnO_4]{[O]}$

(c) toluene $\xrightarrow[HNO_3 + H_2SO_4]{\text{nitration}}$ A $\xrightarrow[KMnO_4]{[O]}$

(d) all these methods

110. Which of the following groups are electron-releasing?

(a) $—NH_2$ (b) $—CH_3$

(c) $—NO_2$ (d) —CN

111. Which of the following groups are electron-withdrawing?

(a) —COOH (b) $—C_6H_5$

(c) $—NH_2$ (d) —OH

112. The Friedel–Crafts reaction of benzene with *n*-butyl chloride at 0°C produces

(a) $C_6H_5—CH_2CH_2CH_2CH_3$

(b) $C_6H_5\underset{}{\overset{\displaystyle CH_3 \atop |}{C}}H—CH_2CH_3$

(c) $C_6H_5—CH_2—\underset{\displaystyle | \atop CH_3}{C}H—CH_3$

(d) all of these

113. Which of the following statements are correct?

(a) An activating group is an electron-releasing group.

(b) An activating group activates all positions of the benzene ring.

(c) The effect of any group—whether activating or deactivating—is the strongest at the ortho- and para-positions in the benzene ring.

(d) An activating group activates only the ortho- and para-positions in the benzene ring.

114. The necessary conditions for halogenation are

(a) low temperature

(b) darkness

(c) the presence of a halogen carrier

(d) none of these

115. The major products formed in the reaction of toluene with chlorine in the presence of ferric chloride are

(a) *o*-chlorotoluene (b) *m*-chlorotoluene

(c) *p*-chlorotoluene (d) benzyl chloride

116. Benzene can undergo

(a) substitution (b) addition

(c) elimination (d) oxidation

117. Which of the following statements about the nitration of aromatic compounds are correct?

(a) The rate of nitration of toluene is greater than that of benzene.

(b) The rate of nitration of benzene is almost the same as that of hexadeutrobenzene.

(c) The rate of nitration of benzene is greater than that of hexadeutrobenzene.

(d) Nitration is an electrophilic substitution reaction.

118. Which of the following reactions can be conveniently carried out?

(a) Benzene + $I_2 \longrightarrow$ iodobenzene

(b) Toluene + $I_2 \xrightarrow{HNO_3}$ *o*- and *p*-iodotoluene

(c) Toluene + $Cl_2 \xrightarrow{\text{light}}$ benzyl chloride

(d) Benzene + $Cl_2 \xrightarrow{h\nu}$ benzene hexachloride

119. Which of the following intermediate stages are possible in the conversion of benzaldehyde into benzoin by reaction with HCN?

(a) $\begin{array}{c} \quad\quad\;\; CN \\ \quad\quad\;\; | \\ C_6H_5—C—H \\ \quad\quad\;\; | \\ \quad\quad\;\; OH \end{array}$ (b) $\begin{array}{c} \quad\quad\;\; CN \\ \quad\quad\;\; | \\ C_6H_5—\overset{\ominus}{C}: \\ \quad\quad\;\; | \\ \quad\quad\;\; OH \end{array}$

(c) $\begin{array}{c} \quad\quad\;\; CN\;\;\; H \\ \quad\quad\;\; |\quad\;\; | \\ C_6H_5—C—C—C_6H_5 \\ \quad\quad\;\; |\quad\;\; | \\ \quad\quad\;\; OH\;\; OH \end{array}$ (d) None of these

120. Which of the groups, if present in the benzene nucleus, are *o*- and *p*-directing?

(a) $—CH_3$ (b) $—C\equiv N$

(c) $—NH_2$ (d) $—CHO$

121. Which of the following are electrophiles?

(a) $R—\bar{C}H_2$ (b) Cl^-

(c) $>C=O$ (d) $\overset{+}{N}O_2$

122. Aniline, on acetylation followed by bromination (Br_2/CH_3COOH) and subsequent hydrolysis, gives

(a) *o*-bromoaniline (b) *p*-bromoaniline

(c) *m*-bromoaniline (d) *m*-bromoacetanilide

123. Which of the following can be represented by a resonance hybrid?

(a) Sulphur trioxide (b) Benzene

(c) Toluene (d) Benzene sulphonic acid

124. Iodobenzene can be obtained by

(a) $C_6H_6 + I_2 \longrightarrow$ (b) $C_6H_6 + I_2 \xrightarrow{HNO_3}$

(c) $C_6H_5N_2^+Cl^- + KI \longrightarrow$ (d) $C_6H_6 + HI \longrightarrow$

Answers

1. c	**2.** d	**3.** c	**4.** c	**5.** c
6. b	**7.** a	**8.** b	**9.** b	**10.** a
11. c	**12.** a	**13.** a	**14.** a	**15.** b
16. c	**17.** b	**18.** b	**19.** d	**20.** a
21. a	**22.** a	**23.** c	**24.** a	**25.** a
26. c	**27.** a	**28.** c	**29.** b	**30.** a
31. a	**32.** b	**33.** a	**34.** b	**35.** b
36. b	**37.** c	**38.** a	**39.** a	**40.** b
41. c	**42.** b	**43.** d	**44.** d	**45.** a
46. a	**47.** c	**48.** c	**49.** a	**50.** a
51. b	**52.** a	**53.** c	**54.** d	**55.** c
56. c	**57.** c	**58.** d	**59.** c	**60.** d
61. b	**62.** b	**63.** d	**64.** a	**65.** b
66. c	**67.** b	**68.** c	**69.** b	**70.** b
71. b	**72.** a	**73.** a	**74.** b	**75.** a
76. c	**77.** d	**78.** b	**79.** c	**80.** c
81. d	**82.** a	**83.** b	**84.** b	**85.** a
86. c	**87.** b	**88.** d	**89.** c	**90.** a, b
91. a, c, d	**92.** a, b, c, d	**93.** a, b, c	**94.** a, b, c	**95.** a, b, d
96. a, b, c	**97.** a, b, c	**98.** a, b, c	**99.** a, c	**100.** a, b
101. a, b, c, d	**102.** a, b	**103.** a, b	**104.** a, b, c	**105.** a, b

106. a, b	**107.** c, d	**108.** a, d	**109.** a, b	**110.** a, b
111. a, b	**112.** a, b	**113.** a, b, c	**114.** a, b, c	**115.** a, c
116. a, b, d	**117.** a, c, d	**118.** b, c, d	**119.** a, b, c	**120.** a, c
121. c, d	**122.** a, b	**123.** a, b, c, d	**124.** b, c	

Hints to More Difficult Problems

2. An aromatic compound has $(4n + 2)$ π-electrons (Huckel rule).

6. The COOH group is *m*-directing.

8. $C_6H_5COCH_2C_6H_5$ will behave like alkyl benzene. So the reaction (bromination) will take place preferably at the *p*-position. The attack at the *o*-position is muted by steric hindrance.

10. A conjugated diene is the most stable.

11. According to the Huckel rule, a conjugated polyene will be aromatic only if it contains $(4n + 2)$ π-electrons. If it has $4n$ π- electrons, it will be nonaromatic.

12. The addition of an alkene molecule with 2 π-electrons to a conjugated diene (4 π-electrons) is called a [4 + 2] cycloaddition reaction.

15. A $\overset{\circ}{2}$ carbocation is more stable than a $\overset{\circ}{1}$ carbocation. Therefore, wherever possible, a $\overset{\circ}{1}$ carbocation gets isomerized or converted into a $\overset{\circ}{2}$ carbocation.

24. If all the hydrogens in an aromatic compound are equivalent, only one monosubstitution product is obtained from it.

31. The Friedel–Crafts reaction of benzene with an alkyl halide gives alkyl-substituted benzene.

33. See the hint to Q. 31.

36. If all the available hydrogens are equivalent in a disubstituted aromatic compound, only one monosubstituted product is obtained from it.

100. See the hint to Q. 2.

106. The methyl group is *o*- and *p*-directing.

116. Benzene cannot undergo an elimination reaction.

118. Iodobenzene cannot be obtained by the reaction of benzene with iodine. The reaction will take place only in the presence of an oxidizing agent.

❑

6

Compounds Containing Oxygen: Alcohols, Phenols, Ethers, Aldehydes, Ketones, Carboxylic Acids and Their Derivatives

• *Type 1* •

Choose the correct option. Ony one option is correct.

1. The final product (IV) in the sequence of reactions

$$\underset{\displaystyle CH_3}{\overset{\displaystyle CH_3CHOH}{|}} \xrightarrow{PBr_3} I \xrightarrow[\text{ether}]{Mg} II \xrightarrow{\underset{\diagdown\; O \;\diagup}{CH_2\text{—}CH_2}} III \xrightarrow{H_2O} IV$$

is

(a) $CH_3\text{—}\underset{\displaystyle CH_3}{\overset{\displaystyle CHOCH_2CH_2OH}{|}}$ (b) $CH_3\text{—}\underset{\displaystyle CH_3}{\overset{\displaystyle CHCH_2CH_2Br}{|}}$

(c) $CH_3\text{—}\underset{\displaystyle CH_3}{\overset{\displaystyle CH\text{—}CH_2CH_2OH}{|}}$ (d) $CH_3\text{—}\underset{\displaystyle CH_3}{\overset{\displaystyle CHOCH_2CH_3}{|}}$

2. By which of the following procedures can ethyl *n*-propyl ether be obtained?

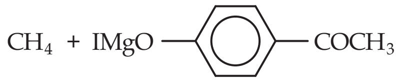
(a) $C_2H_5OH \xrightarrow{HBr} I \xrightarrow[\text{ether}]{Mg} II \xrightarrow{H_2O} III \xrightarrow[CH_3CH_2Br]{Na}$

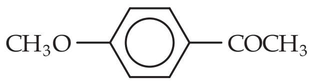
(b) $C_2H_5OH \xrightarrow{HBr} I \xrightarrow[\text{ether}]{Mg} II \xrightarrow[2 \cdot H_3\overset{+}{O}]{1 \cdot CH_2O} III \xrightarrow[CH_3CH_2Br]{Na}$

(c) $C_2H_5OH + H_2SO_4 \xrightarrow{140°C}$

(d) $C_2H_5OH + \text{conc. } H_2SO_4 \xrightarrow{180°C} I \xrightarrow{CH_3CH_2CH_2Br}$

3. The reaction of 1 mol each of *p*-hydroxyacetophenone and methyl magnesium iodide will give

(a)


(b)


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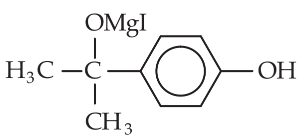
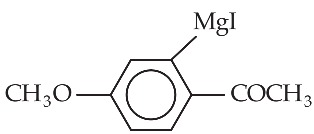


(d)


4. Which of the following can be used for the synthesis of 3-methyl-1-butanol?

(a) $n\text{-}C_3H_7MgBr + CH_3CHO$

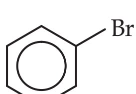
(b) $(CH_3)_2CHCH_2MgBr + CH_2O$

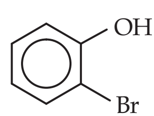
(c)

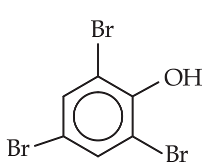
$$C_2H_5MgBr + CH_3-\overset{\overset{\displaystyle O}{\|}}{C}-CH_3$$

(d) $(CH_3)_3CMgBr + CH_2O$

5. The product obtained by the reaction of HBr with phenol is

(a)


(b)


(c)


(d) There is no reaction.

6. The conversion

$$CH_3-\overset{\overset{\displaystyle O}{\|}}{C}-CH_2CH_2CO_2CH_3 \longrightarrow CH_3-\overset{\overset{\displaystyle OH}{|}}{C}H-CH_2CH_2CH_2OH$$

can be effected using

(a) $LiAlH_4$ and then H^+ (b) $NaBH_4$ and then H^+

(c) H_2/Pt-C (d) none of these

7. The conversion

$$CH_3-\overset{\overset{\displaystyle O}{\|}}{C}-CH_2CH_2CO_2CH_3 \longrightarrow CH_3-\overset{\overset{\displaystyle OH}{|}}{C}H-CH_2CH_2CO_2CH_3$$

can be effected using

(a) $LiAlH_4$ and then H^+ (b) $NaBH_4$ and then H^+

(c) H_2/carbon (d) none of these

8. Among the following, which will react most rapidly with HBr?

(a) $C_6H_5CH_2CH_2CH_2OH$ (b) $C_6H_5\underset{\underset{\displaystyle OH}{|}}{C}HCH_2CH_3$

(c) $C_6H_5CH_2\underset{\underset{\displaystyle OH}{|}}{C}H-CH_3$ (d) $CH_3-\overset{\overset{\displaystyle CH_3}{|}}{\underset{\underset{\displaystyle CH_3}{|}}{C}}-CH_2OH$

9. By which of the following methods is phenol prepared on a commercial scale?

(a) Chlorobenzene + NaOH (350°C) and then H^+

(b) Benzene + O_2

(c) Toluene + O_2 and then H^+, Δ

(d) None of these

10. The product X in the reaction

$$CH_3-\overset{\overset{\displaystyle O}{\|}}{C}-CH_3 + CN^- \xrightarrow{H^+} C_4H_7NO \xrightarrow[H_2SO_4]{H_2O} X$$

is

(a) $CH_3CH_2COOCH_3$ (b) $CH_3\underset{\underset{\displaystyle CN}{|}}{C}HCH_3$

(c) $CH_2=\overset{\overset{\displaystyle CH_3}{|}}{C}-COOH$ (d) $CH_3CH=CHCOOH$

11. Which of the following reactions will give benzaldehyde?

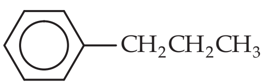
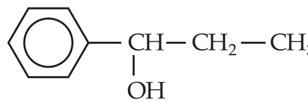
(a) $C_6H_5CH_2Cl \xrightarrow[H_2O,\,\Delta]{OH^-}$ (b) $C_6H_5CH(OCH_3)_2 \xrightarrow[H_2O]{H^+}$

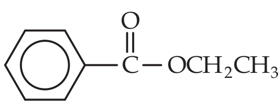
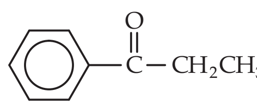
(c) $C_6H_5COOH \xrightarrow[2 \cdot H_2O]{1 \cdot LiAlH_4}$ (d) None of these

12. The final product (III) obtained in the reaction sequence

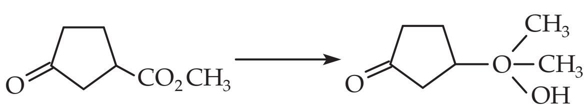
$$CH_3CH_2COOH \xrightarrow{PCl_3} I \xrightarrow[AlCl_3]{C_6H_6} II \xrightarrow[\text{base, heat}]{NH_2NH_2} III$$

is

(a)  (b) 

(c)  (d) 

13. By which of the following reagents can the following conversion be effected?



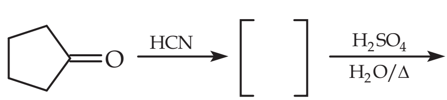
(a) $2CH_3MgBr$ and then H_3O^+

(b) $HOCH_2—CH_2OH$, H^+; $LiAlH_4$, ether; $2CH_3MgBr$; H_3O^+

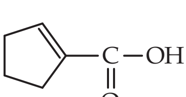
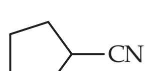
(c) $HOCH_2—CH_2OH$, H^+; $2CH_3MgBr$; H_3O^+

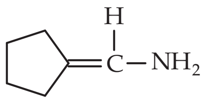
(d) $HOCH_2—CH_2OH$, H^+; H_2, Pt; CH_3OH, H^+

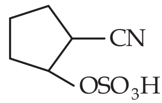
14. The major product obtained in the reaction



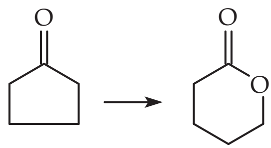
is

(a)  (b) 

(c) 

(d) 

15. The conversion



can be effected by using the reagent

(a) H_2O, H_2SO_4

(b) O_2

(c) $C_6H_5-\overset{\overset{\displaystyle O}{\|}}{C}OOH$

(d) CrO_3, H_2SO_4

16. The final product (III) obtained in the reaction

$$CH_3-\underset{CH_3}{\overset{CH_3}{\underset{|}{\overset{|}{C}}}}-CHO + CH_3CH_2CHO \xrightarrow{OH^-} I \xrightarrow[-H_2O]{H^+} II \xrightarrow{NaBH_4} III$$

is

(a) $CH_3-\underset{CH_3}{\overset{CH_3}{\underset{|}{\overset{|}{C}}}}-CH=CHCH_2CH_2OH$

(b) $CH_3-\underset{CH_3}{\overset{CH_3}{\underset{|}{\overset{|}{C}}}}-CH=\underset{CH_3}{\underset{|}{C}}-CH_2OH$

(c) $CH_3-\underset{CH_3}{\overset{CH_3}{\underset{|}{\overset{|}{C}}}}-CH_2-\underset{CH_3}{\underset{|}{CH}}-CH_2OH$

(d) $CH_3-\underset{CH_3}{\overset{CH_3}{\underset{|}{\overset{|}{C}}}}-CH_2-CH_2CH_2OH$

17. The product obtained in the reaction

$$CH_3CH{=}CHCO_2C_2H_5 \xrightarrow[C_2H_5OH/CH_3COOH]{NaCN}$$

is

(a) $CH_3CH_2\underset{\underset{CN}{|}}{C}HCO_2C_2H_5$ (b) $CH_3CH{=}CHCH_2CN$

(c) $CH_3CH{=}CHCN$ (d) $CH_3\underset{\underset{CN}{|}}{C}H{-}CH_2CO_2C_2H_5$

18. The major product obtained in the reaction

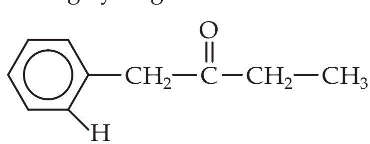
$$(CH_3)_2C{=}CH{-}\underset{\underset{O}{\|}}{C}{-}CH_3 \xrightarrow[2.\ H_3O^+]{1.\ CH_3MgBr}$$

is

(a) $(CH_3)_3CCH_2COCH_3$ (b) $(CH_3)_2C{=}CH\underset{\underset{OH}{|}}{C}{-}(CH_3)_2$

(c) $(CH_3)_2CH{-}\underset{\underset{CH_3}{|}}{C}HCOCH_3$ (d) $(CH_3)_2C{=}CH{-}\overset{\overset{OH}{|}}{\underset{\underset{H}{|}}{C}}{-}CH_3$

19. Which of the following hydrogens will be the most acidic?



(d) (c) (b) (a)

20. Which of the following alcohols will dehydrate most rapidly when treated with H_2SO_4?

(a) $CH_3{-}\underset{\underset{OH}{|}}{C}H{-}\overset{\overset{CH_3}{|}}{\underset{\underset{CH_3}{|}}{C}}{-}CH_3$ (b) $CH_3{-}\underset{\underset{CH_3}{|}}{C}H{-}\underset{\underset{OH}{|}}{C}H{-}CH_3$

(c) $CH_3{-}\overset{\overset{CH_3}{|}}{\underset{\underset{OH}{|}}{C}}{-}\underset{\underset{CH_3}{|}}{C}H{-}CH_3$ (d) $CH_3{-}CH_2CH_2CH_2OH$

21. The oxidation of 2-hexanol with H_2CrO_4 gives

(a) CH_3CO_2H (b) $CH_3(CH_2)_2CO_2H$

(c) $CH_3(CH_2)_3-\overset{\displaystyle O \atop \|}{C}CH_3$ (d) $CH_3(CH_2)_4CO_2H$

22. Which of the following is the best procedure to make isopropylmethylether using the Williamson method?

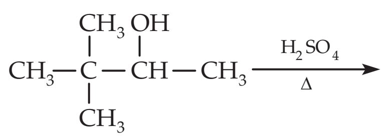
(a) $CH_3OH + (CH_3)_2CHOH + H_2SO_4$

(b) $CH_3OH + (CH_3)_2CHCH_2OH + H_2SO_4$

(c) $CH_3ONa + (CH_3)_2CHBr$

(d) $CH_3I + (CH_3)_2CHONa$

23. Which is the major product obtained in the following reaction?



(a) $(CH_3)_2C{=}C(CH_3)_2$ (b) $(CH_3)_3C{-}CH{=}CH_2$

(c) $(CH_3)_2C{=}CHCH_3$ (d) $(CH_3)_2C{=}CHCH_2CH_3$

24. Among the following, which is the strongest acid?

(a) $CHF_2{-}CH_2{-}CH_2{-}COOH$ (b) $CH_3{-}CH_2{-}CF_2{-}COOH$

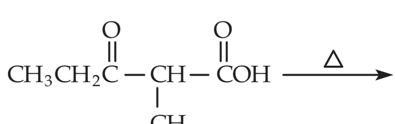
(c) $CH_2F{-}CHF{-}CH_2{-}COOH$ (d) $CH_3{-}CF_2{-}CH_2{-}COOH$

25. Which of the following compounds can form a δ-lactone?

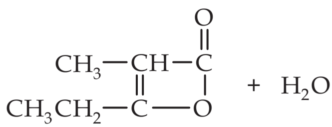
(a) $HOOCCH_2CH_2CH_2COOH$ (b) $CH_3CH_2\underset{\displaystyle | \atop OH}{CH}{-}CH_2COOH$

(c) $HOCH_2CH_2CH_2CH_2COOH$ (d) $CH_3\underset{\displaystyle | \atop OH}{CH}{-}CH_2CH_2COOH$

26. The products obtained in the reaction



are

(a) 

(b) $CH_3CH_2\overset{\overset{\displaystyle O}{\|}}{C}CH_2CH_3 \; + \; CO_2$

(c) $CH_3CH_2\underset{\underset{\displaystyle CH_3}{|}}{C}H\overset{\overset{\displaystyle O}{\|}}{C}OH \; + \; CO$

(d) none of these

27. The product obtained in the reaction

$$C_6H_5CO_2C_2H_5 + CH_3CO_2C_2H_5 \xrightarrow[2.\ H^+]{1.\ NaOEt}$$

is

(a) $C_6H_5COCH_2CO_2C_2H_5$

(b) $C_6H_5\underset{\underset{\displaystyle OH}{|}}{C}H{-}CH_2CO_2C_2H_5$

(c) $C_6H_5CH_2CO_2C_2H_5$

(d) $C_6H_5CO_2CH_2CO_2C_2H_5$

28. The final product (III) obtained in the reaction sequence

$$CH_3\overset{\overset{\displaystyle O}{\|}}{C}CH_2\overset{\overset{\displaystyle O}{\|}}{C}OC_2H_5 \xrightarrow[2.\ C_6H_5CH_2Br]{1.\ NaOEt} \mathrm{I} \xrightarrow[2.\ H_3O^+]{1.\ NaOH} \mathrm{II} \xrightarrow[-CO_2]{heat} \mathrm{III}$$

is

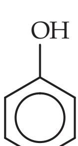
(a) $CH_3\overset{\overset{\displaystyle O}{\|}}{C}CH_2C_6H_5$

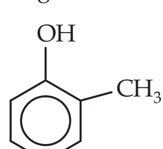
(b) $C_6H_5CH_2\overset{\overset{\displaystyle O}{\|}}{C}OC_2H_5$

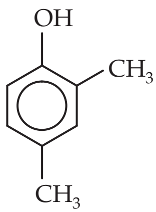
(c) $C_6H_5CH_2CH_2\overset{\overset{\displaystyle O}{\|}}{C}CH_3$

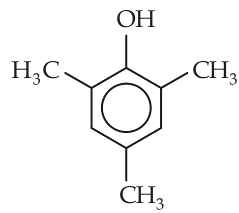
(d) none of these

29. Which of the following compounds will not give bakelite-type resins?

(a) 

(b) 

(c) 

(d) 

30. The major product obtained in the reaction

$$CH_3CH_2C\equiv CH \xrightarrow[H_2O]{Hg^{++},\ H_3O^+}$$

is

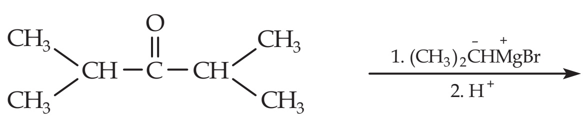
(a) $CH_3CH_2CH_2CH(OH)_2$

(b) $CH_3CH_2CH{=}CHOH$

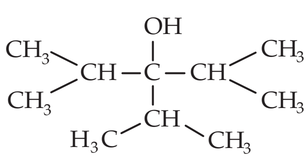
(c) $CH_3CH_2CH_2CHO$

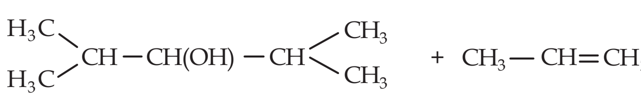
(d) $CH_3CH_2\underset{\underset{O}{\|}}{C}-CH_3$

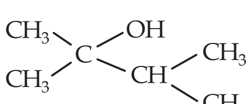
31. The product obtained in the reaction



is

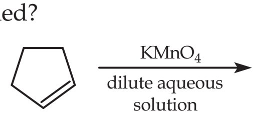
(a) 

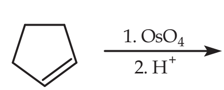
(b) 

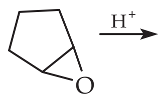
(c) 

(d) There is no reaction.

32. By which the following reactions can *trans*-cyclopentane-1,2-diol be obtained?

(a) 

(b) 

(c) 

(d) None of these

33. The order of reactivity towards nucleophilic addition in CH_2O (I), CH_3CHO (II) and CH_3COCH_3 (III) is

(a) I > II > III (b) III > II > I (c) II > I > III (d) III > I > II

34. The conversion

$$CH_3CH{=}CHCHO \longrightarrow CH_3CH{=}CHCH_2OH$$

can be achieved by using

(a) H_2-NI (b) $LiAlH_4$

(c) $NaBH_4$ (d) none of these

35. The ease of reduction of C_6H_5COCl (I), C_6H_5CHO (II), $C_6H_5COCH_3$ (III) and

$$C_6H_5{-}\overset{\overset{\displaystyle O}{\|}}{C}{-}OC_2H_5 \ \text{(IV)}$$

by hydrogen over a palladium catalyst follows the order

(a) I > II > III > IV (b) IV > III > II > I

(c) II > III > I > IV (d) III > II > I > IV

36. The trans-hydroxylation of cyclohexene can be done by

(a) dilute $KMnO_4$

(b) using OsO_4

(c) converting cyclohexene into an epoxide and then opening the epoxide ring

(d) none of these

37. Consider the following reaction.

$$CH_3CH_2\underset{\underset{\displaystyle O}{\|}}{C}CH_3 + H_2 \xrightarrow{Ni} CH_3CH_2\underset{\underset{\displaystyle OH}{|}}{CH}-CH_3$$

Which of the following statements is correct?

(a) The product is (R)–(–)-2-butanol.

(b) The product is (S)–(+)-2-butanol.

(c) The product is in racemic form.

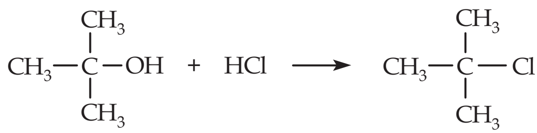
(d) None of these.

38. The relative acidities of H_2O (I), CH_3OH (II), $CH_3C{\equiv}CH$ (III), NH_3 (IV) and CH_4 (V) follow the order

(a) II > I > IV > III > V (b) I > II > III > IV > V

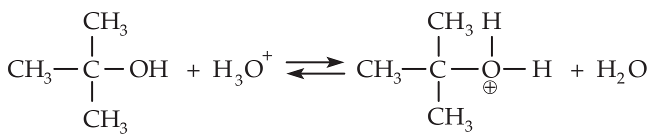
(c) III > V > IV > I > II (d) II > I > III > IV > V

39. In the reaction

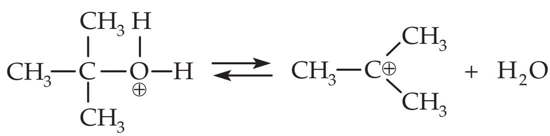


the rate-determining step is

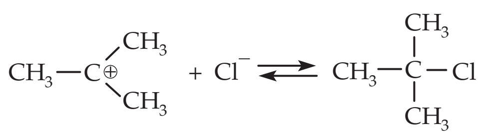
(a)



(b)

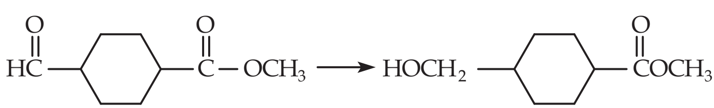


(c)



(d) all steps take place with equal ease.

40. The reduction

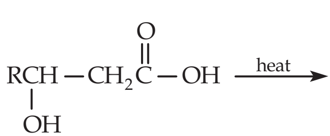


can be achieved by using

(a) $NaBH_4$ (b) $LiAlH_4$

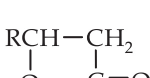
(c) $CuO \cdot CuCN_2O_4$ (d) none of these

41. The product obtained in the reaction

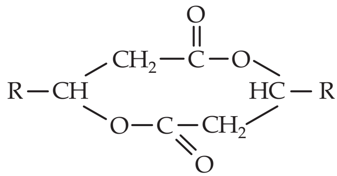


is

(a)



(b)



(c) RCH=CHCOOH

(d) none of these

42. Arrange phenol (I), cyclohexanol (II), 2,4,6-trinitrophenol (III) and acetic acid (IV) in order of acidity.

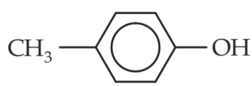
(a) III > IV > I > II (b) I > II > III > IV

(c) III > I > II > IV (d) II > I > IV > III

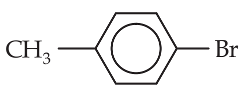
43. The final product obtained in the reaction

is

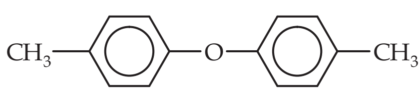
(a)



(b)



(c)



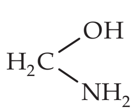
(d) none of these

44. The final product obtained in the reaction

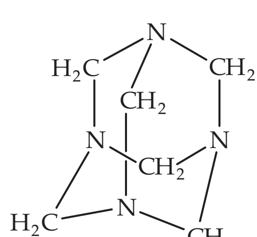
$$CH_2O + NH_3 \longrightarrow [\quad] \xrightarrow[Ac_2O]{HNO_3}$$

is

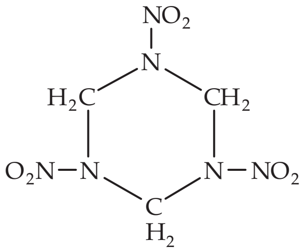
(a)



(b)



(c)



(d) none of these

45. The major product obtained in the reaction

$$CH_2{=}CH{-}\overset{O}{\overset{\|}{C}}{-}CH_3 \quad + \quad HCN \xrightarrow{\bar{O}H}$$

is

(a) $CH_2{=}CH{-}\underset{CN}{\underset{|}{\overset{OH}{\overset{|}{C}}}}{-}CH_3$

(b) $NC{-}CH_2{-}CH_2{-}\overset{O}{\overset{\|}{C}}{-}CH_3$

(c) $CH_2{=}CH{-}\underset{COOH}{\underset{|}{\overset{OH}{\overset{|}{C}}}}{-}CH_3$

(d) none of these

46. The product obtained in the reaction

$$CH_2{=}CH{-}\overset{O}{\overset{\|}{C}}{-}H \quad + \quad HCl \longrightarrow$$

is

(a) $ClCH_2{-}CH_2{-}\overset{O}{\overset{\|}{C}}{-}H$

(b) $CH_3{-}\underset{Cl}{\underset{|}{CH}}{-}\overset{O}{\overset{\|}{C}}{-}H$

(c) $CH_2{=}CH{-}\overset{O}{\overset{\|}{C}}{-}OH$

(d) none of these

47. The reaction

$$H{-}\overset{O}{\overset{\|}{C}}{-}\overset{O}{\overset{\|}{C}}{-}H \quad + \quad \overset{\ominus}{O}H \longrightarrow H{-}\underset{H}{\underset{|}{\overset{OH}{\overset{|}{C}}}}{-}C{\substack{\diagup\!\!\diagup O \\ \diagdown OH}}$$

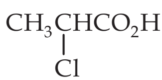
is known as

(a) aldol condensation
(b) the Cannizzaro reaction
(c) the internal Cannizzaro reaction
(d) benzilic acid rearrangement

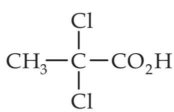
48. The product obtained in the reaction

$$CH_3CH_2CO_2H \xrightarrow{Cl_2/P}$$

is

(a) 

(b) $ClCH_2CH_2CO_2H$

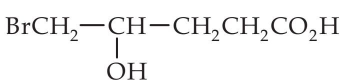
(c) 

(d) $Cl_2CHCH_2CO_2H$

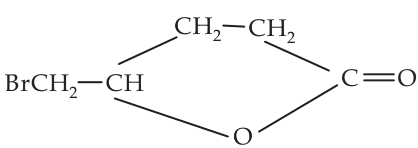
49. The final product obtained in the reaction

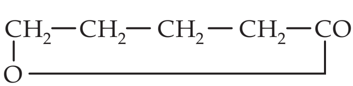
$$CH_2{=}CHCH_2CH_2CO_2H \xrightarrow{HOBr}$$

is

(a) 

(b) $HOCH_2{-}CH_2CH_2CH_2CO_2H$

(c) 

(d) 

50. Which of the following is a primary alcohol?
(a) Butan-1-ol (b) Butan-2-ol
(c) Propan-2-ol (d) 2-Dimethylhexane-4-ol

51. How many isomers of $C_5H_{11}OH$ will be primary alcohols?
(a) Four (b) Five
(c) Three (d) Two

52. Ethyl iodide reacts with moist silver oxide to produce
(a) ethane (b) propane
(c) ethyl alcohol (d) diethyl ether

53. The reduction of R—COOH to R—CH_2OH can be effected by

(a) sodium/alcohol (b) Zn/HCl

(c) $LiAlH_4$ (d) aluminium isopropoxide

54. The alkaline hydrolysis of esters is known as

(a) hydration (b) esterification

(c) dehydration (d) saponification

55. The conversion $CH_3CH_2CHO \longrightarrow CH_3CH_2CH_2OH$ can be effected by

(a) $NaBH_4$ (b) Zn/HCl

(c) H_2/Ni (d) Na + alcohol

56. The conversion $CH_2{=}CH{-}CHO \longrightarrow CH_2{=}CHCH_2OH$ can be effected by

(a) Na + alcohol (b) Zn + HCl

(c) H_2/Ni (d) $LiAlH_4$

57. The boiling points of isomeric alcohols follow the order

(a) primary > secondary > tertiary

(b) tertiary > secondary > primary

(c) secondary > tertiary > primary

(d) They do not follow any order.

58. The acidic character of $\overset{\circ}{1}, \overset{\circ}{2}, \overset{\circ}{3}$ alcohols, H_2O and RC≡CH is of the order

(a) $H_2O > \overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3} > RC{\equiv}CH$

(b) $RC{\equiv}CH > \overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1} > H_2O$

(c) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3} > H_2O > RC{\equiv}CH$

(d) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1} > H_2O > RC{\equiv}CH$

59. The conversion of alcohols into chloro-compounds by reaction with $SOCl_2$ follows the order

(a) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3}$ (b) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1}$

(c) $\overset{\circ}{2} > \overset{\circ}{1} > \overset{\circ}{3}$ (d) $\overset{\circ}{1} = \overset{\circ}{2} > \overset{\circ}{3}$

60. C_2H_5OH reacts with halogen acids in the presence of $ZnCl_2$ to form C_2H_5X. Its reactivity with HI, HBr and HCl follows the order

(a) HI > HBr > HCl (b) HCl > HBr > HI

(c) HCl > HI > HBr (d) HBr=HCl > HI

61. The dehydration of $\overset{\circ}{1}$, $\overset{\circ}{2}$ and $\overset{\circ}{3}$ alcohols follows the order

(a) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3}$ (b) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1}$

(c) $\overset{\circ}{2} > \overset{\circ}{1} > \overset{\circ}{3}$ (d) There is no such order.

62. In the following reaction sequence

$$R{-}OH \xrightarrow{P+I_2} R{-}I \xrightarrow{AgNO_2} RNO_2 \xrightarrow{HNO_2} \text{no reaction.}$$

the alcohol is a

(a) primary alcohol
(b) secondary alcohol
(c) tertiary alcohol
(d) phenol

63. The acidity of the compounds RCOOH, H_2CO_3, C_6H_5OH, ROH decreases in the order

(a) $RCOOH > H_2CO_3 > C_6H_5OH > ROH$
(b) $C_6H_5OH > RCOOH > H_2CO_3 > ROH$
(c) $ROH > C_6H_5OH > RCOOH > H_2CO_3$
(d) $H_2CO_3 > RCOOH > C_6H_5OH > ROH$

64. The acidity of *p*-nitrophenol (I), *o*-nitrophenol (II), *m*-nitrophenol (III) and phenol (IV) decreases in the order

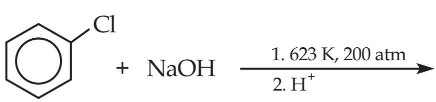
(a) I > II > III > IV
(b) IV > I > II > III
(c) II > III > I > IV
(d) III > II > I > IV

65. The acidities of phenol (I), *p*-cresol (II), *m*-cresol (III) and *o*-cresol (IV) follow the order

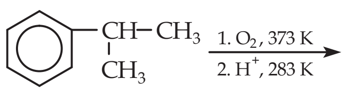
(a) I > II > III > IV
(b) II > I > III > IV
(c) III > I > II > IV
(d) IV > III > II > I

66. Which of the following represents the Dow process for the manufacture of phenol?

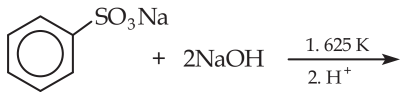
(a)



(b)



(c)



(d) None of these

67. Arrange the following in order of decreasing acidic strength.
p-nitrophenol (I), *p*-cresol (II), *m*-cresol (III), phenol (IV)

(a) I > II > III > IV
(b) IV > III > II > I
(c) I > III > II > IV
(d) III > II > I > IV

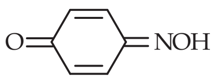
68. Arrange the following in order of decreasing acidic strength.
2,4,6-trinitrophenol (I), 2,4-dinitrophenol (II), *p*-nitrophenol (III), phenol (IV)

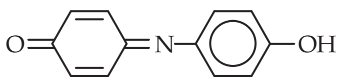
(a) I > II > III > IV
(b) I > III > II > IV
(c) IV > III > II > I
(d) III > II > I > IV

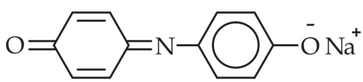
69. Which of the following is constituent of oil of wintergreen?
(a) Aspirin
(b) Salol
(c) Methyl salicylate
(d) None of these

70. In the Liebermann test for phenols, the blue or green colour produced is due to the formation of

(a)


(b)


(c)


(d)


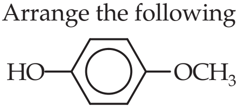
71. When ethylene glycol is heated with a mixture of concentrated HNO_3 and concentrated H_2SO_4, it produces

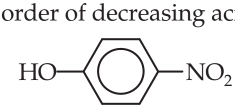
(a) $\begin{array}{l} COOH \\ | \\ COOH \end{array}$
(b) $CO_2 + H_2$
(c) $\begin{array}{l} CH_2ONO_2 \\ | \\ CH_2ONO_2 \end{array}$
(d) $\begin{array}{l} CH_2ONO_2 \\ | \\ CH_2OH \end{array}$

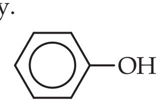
72. When glycerol is heated with an excess of HI, it produces
(a) allyl iodide
(b) propene
(c) glycerol tri-iodide
(d) 2-iodopropane

73. When glycerol is heated with oxalic acid at 503 K, it produces
(a) formic acid
(b) allyl alcohol
(c) acrolein
(d) glyceric acid

74. Arrange the following in order of decreasing acidity.


I


II


III

(a) I > II > III
(b) II > III > I
(c) III > II > I
(d) III > I > II

75. Ethyl alcohol is less acidic than phenol because
(a) the phenoxide ion is more resonance stabilized than phenol
(b) there is more hydrogen bonding in phenol than in ethyl alcohol
(c) the ethoxide ion is less resonance stabilized than ethyl alcohol
(d) phenol has a higher boiling point than ethyl alcohol

76. Which of the following is the most reactive with HCl in the presence of $ZnCl_2$?
(a) $(CH_3)_3COH$ (b) $(CH_3)_2CHCH_2OH$
(c) $(CH_3)_2CHOH$ (d) C_6H_5OH

77. Glycerol reacts with $KHSO_4$ to produce
(a) acrolein (b) oxalic acid
(c) formaldehyde (d) tartaric acid

78. In the reaction of phenol with $CHCl_3$ and aqueous NaOH at 345 K, the species attacking the ring is
(a) $CHCl_3$ (b) $CHCl_2$ (c) $COCl_2$ (d) $:CCl_2$

79. Methanol is manufactured by passing (under pressure) a mixture of water gas and excess hydrogen over heated
(a) platinized asbestos (b) cobalt chloride
(c) Zn and Cr oxides (d) finely divided metal

80. Phenol $\xrightarrow[\text{2. } CO_2/140°C]{\text{1. NaOH}}$ A $\xrightarrow{H^+/H_2O}$ B $\xrightarrow{Ac_2O}$ C

In this reaction, the end product C is
(a) salicylaldehyde (b) salicylic acid
(c) phenyl acetate (d) aspirin

81. Alcohols are soluble in water due to the formation of
(a) covalent bonds (b) ionic bonds
(c) hydrogen bonds with water (d) none of these

82. Which of the following exhibits maximum hydrogen bonding?
(a) Ethyl alcohol (b) Diethyl ether
(c) Ethyl chloride (d) Triethylamine

83. Among the following alcohols, which is the least soluble in water?
(a) Ethyl alcohol (b) C_4H_9OH
(c) $C_5H_{11}OH$ (d) $C_{12}H_{25}OH$

84. The acid strengths of ethanol, isopropanol and tert. butanol decrease in the order
(a) ethanol > isopropanol > tert. butanol
(b) tert. butanol > isopropanol > ethanol

(c) isopropanol > tert. butanol > ethanol
(d) tert. butanol > ethanol > isopropanol

85. The intermediate formed during the dehydration of alcohol is
(a) carbanion (b) carbonium ion
(c) free radical (d) carbene

86. Which of the following produces the most stable carbonium ion upon dehydration?
(a) $(CH_3)_2CHCH_2OH$ (b) $(CH_3)_3COH$
(c) $CH_3(CH_2)_2CH_2OH$ (d) $CH_3—CH(OH)—CH_2—CH_3$

87. An alcohol, on oxidation, produces a ketone with the same number of carbon atoms. When the ketone is oxidized, it yields an acid with a fewer number of carbon atoms. The alcohol could be a
(a) primary alcohol (b) secondary alcohol
(c) tertiary alcohol (d) none of these

88. A compound with the molecular formula C_3H_8O, on vigorous oxidation, produces the acid $C_3H_6O_2$. The compound is
(a) a tertiary alcohol (b) a primary alcohol
(c) a secondary alcohol (d) none of these

89. $CH_3CH_2CH_2OH \xrightarrow[160–180°C]{\text{conc. } H_2SO_4} X \xrightarrow{Br_2} Z \xrightarrow[KOH]{\text{alc.}} Z$

In this reaction sequence, Z is
(a) $CH_3CH(OH)—CH_2OH$ (b) $CH_3—C(OH)=CH_2$
(c) $CH_3—C\equiv CH$ (d) $CH_3CH=CH_2$

90. An alcohol, on dehydration, produces an alkene which on ozonolysis yields two molecules of acetaldehyde. The alcohol is
(a) $CH_3CH_2CH_2OH$ (b) CH_3CH_2OH
(c) $CH_3—CH(CH_3)—CH_2OH$ (d) $CH_3CH_2CH(OH)—CH_3$

91. Glycerine is used in car radiators to
(a) facilitate evaporation
(b) increase the temperature of the water in the radiator
(c) lower the freezing point of the water in the radiator
(d) lower the viscosity of the water in the radiator

92. How much bromine is needed to produce tribromophenol from phenol?
(a) 1.5 mol (b) 4.5 mol (c) 3.0 mol (d) 6.0 mol

93. Ortho-nitrophenol is steam volatile, whereas para-nitrophenol is not. This is due to
(a) the presence of intramolecular hydrogen bonding in *o*-nitrophenol
(b) the presence of intermolecular hydrogen bonding in *o*-nitrophenol
(c) the presence of intermolecular hydrogen bonding in *p*-nitrophenol
(d) none of these

94. When phenol is heated with CCl_4 in alkaline KOH, it produces
(a) salicylaldehyde (b) salicylic acid
(c) *p*-chlorophenol (d) There is no reaction.

95. When phenol is heated with phthalic anhydride and H_2SO_4, it produces
(a) phenol red (b) methyl orange
(c) salicylic acid (d) phenolphthalein

96. In the carbonyl group, the carbon atom is
(a) sp-hybridized (b) sp^2-hybridized
(c) sp^3-hybridized (d) sp^3d-hybridized

97. The C—O—C angle in ether is
(a) 180° (b) 109° 28′ (c) 110° (d) 105°

98. When an excess of ethyl alcohol vapour is passed over heated alumina (250°C), the main product is
(a) ethylene (b) ethane
(c) diethyl ether (d) butane

99. When diethyl ether is heated with concentrated HI, it produces
(a) ethanol (b) iodoform
(c) ethyl iodide (d) methyl iodide

100. When diethyl ether is heated with an excess of PCl_5, it yields
(a) ethyl chloride (b) diethyl ether peroxide
(c) ethanoyl chloride (d) perchlorodiethyl ether

101. Phenetole reacts with HI to produce
(a) $C_6H_5I + CH_3CH_2OH$ (b) $CH_3CH_2I + C_6H_5OH$
(c) $C_6H_5CH_2OH + CH_3CH_2I$ (d) $CH_3CH_2I + C_6H_5OH$

102. The reactivity of halogen acids with ether follows the order
(a) $HI > HBr > HCl$ (b) $HCl > HBr > HI$
(c) $HBr > HI > HCl$ (d) $HCl > HI > HBr$

103. Diethyl ether can be distinguished from ethyl alcohol by its reaction with

(a) Na (b) PCl_5

(c) 2,4-dinitrophenylhydrazine (d) none of these

104. $\underset{\displaystyle Br}{CH_3\underset{|}{C}HCH_3} \xrightarrow[\text{KOH}]{\text{alc.}} A \xrightarrow[\text{peroxide}]{\text{HBr}} B \xrightarrow{CH_3ONa} C$

In the above reaction sequence, the final product is

(a) diethyl ether (b) 1-methoxypropane

(c) isopropyl alcohol (d) propylene glycol

105. Aldehydes undergo

(a) electrophilic addition (b) electrophilic substitution

(c) nucleophilic addition (d) nucleophilic substitution

106. The conversion $CH_3CH{=}CHCHO \longrightarrow CH_3CH{=}CHCH_2OH$ can be effected with

(a) Ni/H_2 (b) 9 BBN

(c) Zn/Hg/HCl (d) none of these

107. Which of the following is the most reactive in nucleophilic addition reactions?

(a) HCHO (b) CH_3CHO

(c) CH_3COCH_3 (d) $CH_3COC_2H_5$

108. Ketones are less reactive than aldehydes because

(a) the C=O group is less polar in ketones

(b) of the electromeric effect

(c) of steric hindrance to the attacking reagent

(d) of none of these

109. Aldehydes and ketones form hydrocarbons by

(a) the Clemmensen reduction (b) the Cannizzaro reaction

(c) the Rosenmund reduction (d) aldol condensation

110. $HC{\equiv}CH \xrightarrow[\text{dil. } H_2SO_4]{HgSO_4} A \xrightarrow{LiAlH_4} B \xrightarrow{P,\ Br_2} C$

In this reaction sequence, C is

(a) ethyl bromide (b) ethylidene bromide

(c) ethylene bromide (d) 1,1-dibromoethane

111. The formation of cyanohydrins from ketones is an example of

(a) electrophilic addition (b) nucleophilic addition

(c) electrophilic substitution (d) nucleophilic substitution

112. When *m*-chlorobenzaldehyde reacts with cold, concentrated KOH at room temperature, the products formed are

(a) *m*-hydroxy benzaldehyde and potassium *m*-chlorobenzoate
(b) *m*-chlorobenzyl alcohol and *m*-hydroxybenzaldehyde
(c) *m*-hydroxybenzyl alcohol and *m*-chlorobenzyl alcohol
(d) *m*-chlorobenzyl alcohol and potassium *m*-chlorobenzoate

113. The reaction of acetamide with NaOBr in an alkaline medium produces

(a) CH_3NH_2 (b) NH_3
(c) $CH_3CH_2NH_2$ (d) CH_3CN

114. Benzaldehyde can be converted into benzyl alcohol by the

(a) Claisen reaction (b) Perkin reaction
(c) Cannizzaro reaction (d) Wurtz reaction

115. Which of the following respond positively to the iodoform test?

(a) 2-Pentanone (b) 1-Pentanal
(c) 3-Pentanone (d) Pentanol

116. Arrange the following in order of decreasing acidity.
$C_6H_5OH, C_2H_5OH, HCOOH, CH_3COOH$

(a) $HCOOH > CH_3COOH > C_6H_5OH > C_2H_5OH$
(b) $CH_3COOH > HCOOH > C_2H_5OH > C_6H_5OH$
(c) $CH_3COOH > C_2H_5OH > HCOOH > C_6H_5OH$
(d) $C_6H_5OH > C_2H_5OH > HCOOH > CH_3COOH$

117. Arrange the following in order of decreasing reactivity in nucleophilic addition reactions.
$CH_3CHO,\ CH_3COCH_3,\ HCHO,\ C_2H_5COCH_3$

(a) $HCHO > CH_3CHO > CH_3COCH_3 > C_2H_5COCH_3$
(b) $CH_3CHO > HCHO > C_2H_5COCH_3 > CH_3COCH_3$
(c) $CH_3CHO > HCHO > CH_3COCH_3 > C_2H_5COCH_3$
(d) $C_2H_5COCH_3 > CH_3COCH_3 > CH_3CHO > HCHO$

118. The reactivities of the carbonyl compounds, HCHO, RCHO and $R_2C{=}O$, in nucleophilic addition reactions are in the following order.

(a) $HCHO > RCHO > R_2CO$ (b) $RCHO > HCHO > R_2CO$
(c) $R_2CO > RCHO > HCHO$ (d) $HCHO > R_2CO < RCHO$

119. In nucleophilic addition reactions, the reactivities of the carbonyl compounds NO_2CH_2CHO (I), $ClCH_2CHO$ (II), CH_3CHO (III) and CH_3CH_2CHO (IV) follow the order

(a) I > II > III > IV (b) IV > III > II > I
(c) I > III > II > IV (d) III > II > I > IV

120. In nucleophilic addition reactions, the reactivities of the carbonyl compounds CH_3COCH_3 (I), $CH_3COCH_2NH_2$ (II) and $CH_3COC(CH_3)_2$ (III) follow the order

(a) I > II > III (b) III > II > I
(c) II > I > III (d) II > III > I

121. The hybridization of C in formaldehyde is

(a) sp (b) sp^2
(c) sp^3 (d) none of these

122. The treatment of ethylidine chloride with aqueous KOH yields

(a) CH_2OHCH_2OH (b) CH_3CHO
(c) HCHO (d) CHOCHO

123. Methylethylketone can be obtained by the oxidation of

(a) 2-butanol (b) 2-propanol
(c) 1-butanol (d) tert. butyl alcohol

124. Which of the following yields a ketone on oxidation?

(a) $CH_3CH_2CH_2CH_2OH$ (b) $CH_3CH_2CHOHCH_3$
(c) $(CH_3)_2CHCH_2CH_2OH$ (d) $CH_3C(CH_3)_2CH_2OH$

125. $CH_3C{\equiv}CH \xrightarrow[HgSO_4]{H_2SO_4}$

The product obtained in this reaction is

(a) acetaldehyde (b) propionic acid
(c) formaldehyde (d) acetone

126. Methyl magnesium chloride reacts with acetyl chloride to produce

(a) ethanol (b) acetone
(c) methanol (d) ether

127. When the product formed by the reaction of $HCOOC_2H_5$ with an excess of CH_3MgI is hydrolysed, it yields

(a) *n*-propyl alcohol (b) isopropyl alcohol
(c) propanol (d) ethanol

128. In the Rosenmund reduction, the catalyst used is

(a) $Pd/BaSO_4$ (b) Raney Ni
(c) Sn/HCl (d) Zn/HCl

129. In the reaction $CH_3CH_2COCl \xrightarrow[H_2]{Pd/BaSO_4}$ X, the product is

(a) propanaldehyde (b) acetaldehyde
(c) acetic acid (d) acetone

130. The reducing agent used in the Stephen reduction is
(a) Sn/HCl (b) Zn/HCl
(c) $SnCl_2$/HCl (d) Na-Hg/alcohol

131. The oxidation of benzene by V_2O_5 in the presence of air produces
(a) benzoic acid (b) benzaldehyde
(c) benzoic anhydride (d) maleic anhydride

132. $C_6H_6 + CO + HCl \xrightarrow{\text{anhyd.}AlCl_3}$
The main product obtained in this reaction is
(a) $C_6H_5CH_3$ (b) C_6H_5CHO (c) $C_6H_5CH_2Cl$ (d) C_6H_5COOH

133. Aldehydes and ketones undergo addition reactions with
(a) phenyl hydrazine (b) hydrazine
(c) semicarbazide (d) hydrogen cyanide

134. The order of reactivity of CH_3CHO (I), $CH_3CH_2COCH_3$ (II) and CH_3COCH_3 (III) is
(a) I > III > II (b) I > II > III
(c) II > I > III (d) III > II > I

135. 1 mol of an organic compound requires 0.5 mol of oxygen to produce an acid. The compound is
(a) an alcohol (b) an aldehyde
(c) a ketone (d) an ether

136. The conversion $CH_3CH{=}CHCHO \longrightarrow CH_3CH{=}CHCOOH$ can be effected by
(a) alkaline $KMnO_4$ (b) acidic $K_2Cr_2O_7$
(c) ammoniacal $AgNO_3$ (d) selenium dioxide

137. An organic compound with the molecular formula C_3H_6O does not respond positively to the silver mirror test with Tollens reagent but produces an oxime. The compound is
(a) $CH_2{=}CHCH_2OH$ (b) CH_3CH_2CHO
(c) $CH_2{=}CHOCH_3$ (d) CH_3COCH_3

138. The aldol condensation of acetaldehyde involves the formation of an intermediate product which is
(a) a carbocation (b) a carbanion
(c) an acetate ion (d) a free radical

139. When acetone is saturated with HCl gas, the final product obtained is
(a) diacetone alcohol (b) phorone
(c) mesityl oxide (d) benzene

140. CH_3CHO and HCHO can be differentiated using

(a) Fehling's solution (b) the Tollens reagent
(c) the Schiff reagent (d) a caustic soda solution

141. The reaction $C_6H_5CHO + CH_3CHO \longrightarrow C_6H_5CH{=}CHCHO$ is called

(a) Claisen condensation (b) aldol condensation
(c) benzoic condensation (d) polymerization

142. Paraldehyde is a

(a) dimer of formaldehyde (b) trimer of acetaldehyde
(c) hexamer of formaldehyde (d) hexamer of acetaldehyde

143. $$C_3H_8O \xrightarrow[K_2Cr_2O_7/H_2SO_4]{[O]} C_3H_6O \xrightarrow[\text{warm}]{I_2\text{ alk.}} CHI_3$$

In this reaction the first compound is

(a) $CH_3CH_2CH_2OH$ (b) $CH_3\underset{\displaystyle OH}{\underset{|}{C}H}{-}CH_3$
(c) $CH_3OCH_2CH_3$ (d) CH_3CH_2CHO

144. An organic compound X with the molecular formula $C_5H_{10}O$ yields phenyl hydrazone and gives a negative response to the iodoform test and Tollens test. It produces *n*-pentane on reduction. The compound could be

(a) pentanal (b) pentanone-2
(c) pentanone-3 (d) amyl alcohol

145. $$C_6H_5CHO + CH_3COCH_3 \xrightarrow{OH^-} C_6H_5CH(OH)CH_2COCH_3 \longrightarrow C_6H_5CH{=}CHCOCH_3$$

This reaction is known as

(a) aldol condensation
(b) cross aldol condensation
(c) the Claisen–Schmidt reaction
(d) none of these

146. The conversion of acetone into diacetone alcohol is carried out in the presence of

(a) dry HCl gas (b) concentrated H_2SO_4
(c) $Ba(OH)_2$ (d) heat

147. $$CH_3CH{=}CH_2 + CO + H_2O \xrightarrow[675\text{ K}]{H_3PO_4} CH_3{-}\underset{\displaystyle CH_3}{\underset{|}{C}H}{-}COOH$$

This reaction is called

(a) the Stevens reaction
(b) the carbonylation reaction
(c) the Gattermannan–Koch reaction
(d) oxidation

148. Arrange the following in order of decreasing acid strength. HCOOH (I), CH_3COOH (II), CH_3CH_2COOH (III), $(CH_3)_2CHCOOH$ (IV)
(a) I > II > III > IV (b) IV > III > II > I
(c) II > I > IV > III (d) I > III > II > IV

149. The acid strengths of the following decrease in the order
(a) $CCl_3COOH > CHCl_2COOH > CH_2ClCOOH > CH_3COOH$
(b) $CH_3COOH > CH_2ClCOOH > CHCl_2CO\ OH > CCl_3COOH$
(c) $CCl_3COOH > CH_3COOH > CH_2ClCO\ OH > CHCl_2COOH$
(d) $CH_2ClCOOH > CHCl_2COOH > CCl_3COOH > CH_3COOH$

150. The acidic strengths of chloro, bromo, iodo and fluoro acetic acids decrease in the order
(a) $FCH_2COOH > ClCH_2COOH > BrCH_2COOH > ICH_2COOH$
(b) $ClCH_2COOH > BrCH_2COOH > FCH_2COOH > ICH_2COOH$
(c) $ICH_2COOH > BrCH_2COOH > ClCH_2COOH > FCH_2COOH$
(d) $BrCH_2COOH > ClCH_2COOH > FCH_2COOH > ICH_2COOH$

151. Methanoic acid is manufactured by the reaction of carbon monoxide and
(a) NaOH (b) dilute HCl
(c) concentrated H_2SO_4 (d) PCl_5

152. $RCOOAg + Br_2 \xrightarrow[\Delta]{CCl_4} R{-}Br + AgBr + CO_2$

This reaction is called the
(a) Wurtz reaction (b) Hunsdiecker reaction
(c) Friedel–Crafts reaction (d) Kolbe reaction

153. $CH_3CH_2CH_2COOH \xrightarrow{\text{Red P/Br}_2} CH_3CH_2\underset{\displaystyle Br}{\underset{|}{CH}}{-}COOH$

This reaction is called the
(a) Cannizzaro reaction
(b) Schrödinger reaction
(c) Hell–Volhard–Zelinsky reaction
(d) Reimer–Tiemann reaction

154. Phthalic acid $\xrightarrow{\Delta}$ A $\xrightarrow{NH_3}$ B $\xrightarrow[H_2O]{NaOH}$ C $\xrightarrow{Br_2/KOH}$ D $\xrightarrow{HCl}$ E

In this reaction, the product E is

(a) *o*-nitrobenzoic acid (b) salicylic acid

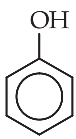
(c) anthranilic acid (d) crotonic acid

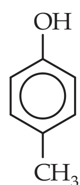
155. Which of the following carboxylic acids undergoes decarboxylation easily?

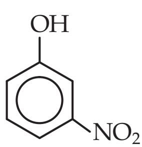
(a) $C_6H_5COCH_2COOH$ (b) $C_6H_5COCOOH$

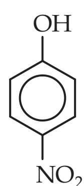
(c) $C_6H_5\underset{\displaystyle OH}{\underset{|}{C}H}—COOH$ (d) $C_6H_5\underset{\displaystyle NH_2}{\underset{|}{C}H}COOH$

156. Which of the following is the most acidic?

(a) 

(b) 

(c) 

(d) 

157. In the Cannizzaro reaction

$$2C_6H_5CHO \xrightarrow{OH^-} C_6H_5CH_2OH + C_6H_5COO^-$$

the slowest step is

(a) the attack by OH^- on the carbonyl group

(b) the transfer of the hydride to the carbonyl group

(c) the exchange of protons can be slow steps

(d) all the above

158. Arrange the following in order of decreasing reactivity with concentrated HCl.

$F—CH_2—\underset{\displaystyle OH}{\underset{|}{C}H}—CH_3$ $F—CH_2—CH_2—\underset{\displaystyle OH}{\underset{|}{C}H}—CH_3$

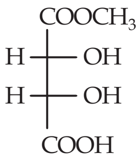
I II

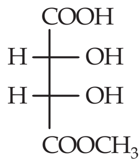
$(CH_3)_2CHOH$ $C_6H_5CH_2OH$

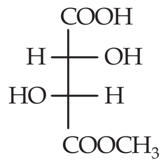
III IV

(a) I > II > III > IV (b) IV > III > II > I
(c) I > III > II > IV (d) IV > III > I > II

159.


A

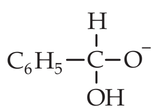

B

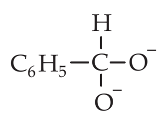

C

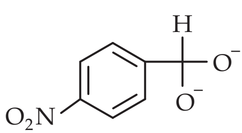
Which of the following statements about the compounds given above is true?

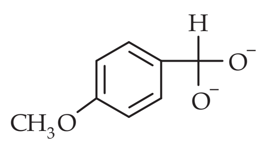
(a) A and B are identical. (b) A and B are diastereomers.
(c) A and C are enantiomers. (d) A and B are enantiomers.

160. Among the following, which intermediate is the best hydride donor in a Cannizzaro reaction?

(a) 

(b) 

(c) 

(d) 

161. Mesotartaric acid and *d*-tartaric acid are

(a) diastereomers (b) racemic mixtures
(c) enantiomers (d) position isomers

162. Racemic tartaric acid is optically inactive due to

(a) internal compensation (b) loss of asymmetric centre
(c) external compensation (d) steric hindrance

163. Which of the following para-substituted benzoic acids is the most acidic?

(a) $Cl—C_6H_5COOH$ (b) $NO_2—C_6H_4COOH$
(c) $HO—C_6H_4—COOH$ (d) $CH_3—C_6H_4—COOH$

164. Which of the following alcohols has the highest boiling point?

(a) $CH_3CH_2CH_2CH_2OH$ (b) $CH_3\underset{\underset{CH_3}{|}}{C}—CH_2OH$

(c) $CH_3CH_2\underset{\substack{| \\ OH}}{CH}-CH_2OH$ (d) $CH_3-\overset{\substack{OH \\ |}}{\underset{\substack{| \\ CH_3}}{C}}-CH_3$

165. Which of the following has the highest boiling point?

(a) $CH_3CH_2CH_2CH_2CH_3$ (b) $CH_3CH_2OCH_2CH_3$

(c) $CH_3CH_2CH_2Cl$ (d) $CH_3CH_2CH_2CH_2OH$

166. An ether reacts with H_2SO_4 to form

(a) an alkyl free radical (b) a zwitterion

(c) an oxonium ion (d) an oxy anion

167. In the reaction $R-S-R \xrightarrow[KMnO_4]{[O]} X$, the product obtained is

(a) a sulphoxide (b) a sulphone

(c) an alkane (d) an alkene

168. Arrange the following in order of decreasing reactivity with nucleophiles.
Acetone (I), ethylmethylketone (II), diethylketone (III)

(a) I > II > III (b) III > II > I

(c) II > I > III (d) III > I > II

169. $CH_3-\overset{\substack{O \\ \|}}{C}-CH_2-CH_2-\overset{\substack{O \\ \|}}{C}-OC_2H_5 \longrightarrow$

$CH_3-\overset{\substack{H \\ |}}{\underset{\substack{| \\ OH}}{C}}-CH_2-CH_2-\overset{\substack{O \\ \|}}{C}-OC_2H_5$

This conversion is effected by using

(a) $NaBH_4$ (b) $LiAlH_4$

(c) Pd-C (d) Raney Ni/H_2

170. The conversion $CH_3CHO \longrightarrow OHC-CHO$ can be effected by

(a) CrO_3 (b) SeO_2 (c) $Br_2/NaOH$ (d) $KMnO_4$

171. Ethylmethylketone, on heating with aluminium isopropoxide and isopropyl alcohol, gives

(a) $CH_3CH_2\underset{\substack{| \\ CH_3}}{CH}-\underset{\substack{| \\ CH_3}}{C}HCH_2CH_3$ (b) $CH_3CH{=}CHCH_3$

(c) $CH_3CH(OH)CH_2CH_3$ (d) $CH_3CH_2CH_2CH_3$

172. Among the following, which are the most acidic?

(a) $CH_3CH_2\underset{\underset{Cl}{|}}{C}HCOOH$

(b) $CH_3CH(Cl)CH_2COOH$

(c) $CH_3CHClCH_2CH_2COOH$

(d) $ClCH_2CH_2CH_2CH_2COOH$

173. The hydrolysis of which of the following takes the longest time?

(a) CH_3COCl

(b) $CH_3COOCOCH_3$

(c) $CH_3\overset{\overset{O}{\|}}{C}-OC_2H_5$

(d) $CH_3-\overset{\overset{O}{\|}}{C}-NH_2$

174. The reactivities of acid halides (I), anhydrides (II), esters (III) and amides (IV) with nucleophilic reagents follow the order

(a) I > II > III > IV

(b) IV > III > II > I

(c) I > III > II > IV

(d) III > II > I > IV

175. Which of the following reactions are feasible?

(a) $CH_3CH_2Br + \overset{+}{Na}O^{-}\underset{\underset{CH_3}{|}}{\overset{\overset{CH_3}{|}}{C}}-CH_3 \longrightarrow CH_3CH_2-O-\underset{\underset{CH_3}{|}}{\overset{\overset{CH_3}{|}}{C}}-CH_3$

(b) $CH_3-\underset{\underset{CH_3}{|}}{\overset{\overset{CH_3}{|}}{C}}-Cl + \overset{+}{Na}O^{-}CH_2CH_3 \longrightarrow CH_3CH_2-O-\underset{\underset{CH_3}{|}}{\overset{\overset{CH_3}{|}}{C}}-CH_3$

(c) Both (a) and (b)

(d) Neither

176. $\underset{\diagdown\ O\ \diagup}{H_2C-CH_2} \xrightarrow[\text{(ii) } H_2O]{\text{(i) } CH_3MgCl} X$

The product obtained in this reaction is

(a) CH_3CH_2OH

(b) $(CH_3)_2CHOH$

(c) $CH_3CH_2CH_2OH$

(d) $HO-CH_2-CH_2-CH_2-CH_2-OH$

177. $(CH_3)_2CH\overset{\overset{CH_3}{|}}{C}HOH \xrightarrow[-H_2O]{\text{acid}} X$

The major product obtained in this reaction is

(a) $(CH_3)_2CHCH{=}CH_2$ (b) $(CH_3)_2C{=}CH{-}CH_3$
(c) a 1 : 1 mixture of (a) and (b) (d) none of these

178. Phenol is soluble in water because
(a) of weak hydrogen bonding between phenol and water molecules
(b) of intermolecular hydrogen bonding between phenol molecules
(c) it has a higher boiling point than that of water
(d) of none of these

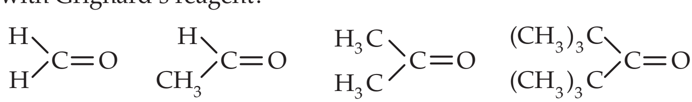
179. The acidities of primary, secondary and tertiary alcohols follow the order
(a) primary > secondary > tertiary
(b) secondary > tertiary > primary
(c) tertiary > secondary > primary
(d) primary > tertiary > secondary

180. The ease of dihydration of $\overset{\circ}{1}$, $\overset{\circ}{2}$ and $\overset{\circ}{3}$ alcohols follows the order
(a) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3}$ (b) $\overset{\circ}{2} > \overset{\circ}{3} > \overset{\circ}{1}$ (c) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1}$ (d) $\overset{\circ}{3} > \overset{\circ}{1} > \overset{\circ}{2}$

181. Arrange acetyl chloride (I), ethyl acetate (II), acetamide (III) and acetic anhydride (IV) in order of reactivity towards nucleophilic acyl substitution.
(a) I > IV > II > III (b) I > II > III > IV
(c) III > II > IV > I (d) IV > III > II > I

182. Which of the following is the best method for making isopropylmethyl ether?
(a) $CH_3I + (CH_3)_2CHOH \longrightarrow$
(b) $CH_3I + (CH_3)_2CHO^- \longrightarrow$
(c) $(CH_3)_2CHI + CH_3O^- \longrightarrow$
(d) $(CH_3)_2CHCl + CH_3OH \longrightarrow$

183. What will be the order of reactivity of the following carbonyl compounds with Grignard's reagent?



(a) I > II > III > IV (b) IV > III > II > I
(c) II > I > IV > III (d) III > II > I > IV

184. In the bromination of acetone, the following three reactions occur.

$$CH_3COCH_3 \longrightarrow CH_3COCH_2Br\,(I)$$

$$CH_3COCH_2Br \longrightarrow CH_3COCHBr_2\,(II)$$

$$CH_3COCHBr_2 \longrightarrow CH_3COCBr_3\,(III)$$

Which of the following reflects the relative ease with which these reactions take place?

(a) I < II < III (b) III < II < I

(c) I < II = III (d) II < I < III

185. On treatment with an alkali, glyoxal gives glycolic acid:

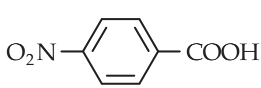
$$OHC\text{—}CHO \xrightarrow{\overline{O}H} HOCH_2\text{—}COOH$$

To which type does this reaction belong?

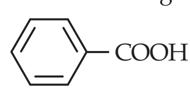
(a) Aldol condensation (b) Knowvenagel condensation

(c) Cannizzaro reaction (d) None of these

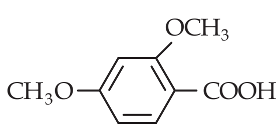
186. Give the order of ease of the esterification of the following acids.



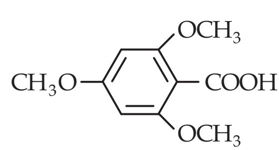
I



II



III



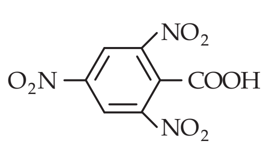
IV

(a) I > II > III > IV (b) IV > III > II > I

(c) II > I > IV > III (d) I > II > III = IV

187. Give the order of ease of decarboxylation of the following acids.

CH_3COOH	$CH_2{=}CH\text{—}CH_2COOH$	$CH_2(COOH)_2$
I	II	III



IV

(a) I > II > III > IV (b) III > IV > II > I

(c) IV > III > II > I (d) I > III > II > IV

188. The reactivities of propyl alcohol (I), isopropyl alcohol (II) and tertiary butyl alcohol (III) with halogen halides follow the order

(a) III > II > I (b) I > II > III

(c) II > I > III (d) III > I > II

189. The reactivities of CH_3OH, $\overset{\circ}{1}$, $\overset{\circ}{2}$ and $\overset{\circ}{3}$ alcohols towards metals follow the order

(a) $CH_3OH > \overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3}$ (b) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3} > CH_3OH$

(c) $CH_3OH > \overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1}$ (d) $CH_3OH > \overset{\circ}{2} > \overset{\circ}{3} > \overset{\circ}{1}$

190. The acidities of H_2O, ROH, NH_3, and RH follow the order

(a) $ROH > NH_3 > RH > H_2O$ (b) $NH_3 > ROH > RH > H_2O$

(c) $H_2O > ROH > NH_3 > RH$ (d) $H_2O > NH_3 > ROH > RH$

191. The order of the basicities of OH^-, OR^-, NH_2^-, R^- is

(a) $OH^- > OR^- > NH_2^- > R^-$ (b) $OR^- > NH_2^- > R^- > OH^-$

(c) $R^- < NH_2^- < OR^- < OH^-$ (d) $OH^- < OR^- < NH_2^- < R^-$

192. Which of the following reactions can be used for the preparation of tert. butylmethyl ether?

(a) $CH_3Br + (CH_3)_3\,C\overset{-}{O}\overset{+}{Na} \longrightarrow$

(b) $(CH_3)_3CCl + CH_3\overset{-}{O}\overset{+}{Na} \longrightarrow$

(c) $(CH_3)_3OH + CH_3Cl \longrightarrow$

(d) $(CH_3)_3CCl + CH_3OH \longrightarrow$

193. For the cleavage of ethers by halogen acids, the order of reactivity of halogen acids is

(a) HI > HBr > HCl

(b) HBr > HI > HCl

(c) HCI > HBr > HI

(d) Ethers do not undergo cleavage.

194. The solubilities of the alcohols

$\underset{\text{I}}{CH_3CH_2CH_2OH}$ $\underset{\text{II}}{CH_3CH_2CH_2CH_2OH}$ $\underset{\text{III}}{CH_3CH_2CH_2CH_2CH_2OH}$

in water follow the order

(a) I > II > III

(b) III > II > I

(c) II > I > III

(d) There is no fixed order of solubility of alcohols in water.

195. The hydrogen bonding ability of $\overset{\circ}{1}, \overset{\circ}{2}$ and $\overset{\circ}{3}$ alcohols is of the order

(a) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3}$ (b) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1}$

(c) $\overset{\circ}{1} > \overset{\circ}{3} > \overset{\circ}{2}$ (d) There is no fixed order.

196. The boiling points of isomeric $\overset{\circ}{1}, \overset{\circ}{2}$ and $\overset{\circ}{3}$ alcohols decrease in the order

(a) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1}$ (b) $\overset{\circ}{3} > \overset{\circ}{1} > \overset{\circ}{2}$

(c) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3}$ (d) There is no fixed order.

197. Arrange $CH_3OH, C_2H_5OH, (CH_3)_2CHOH$ and $(CH_3)_3COH$ in order of decreasing acidity.

(a) $CH_3OH > C_2H_5OH > (CH_3)_2CHOH > (CH_3)_3COH$

(b) $(CH_3)_3COH > (CH_3)_2CHOH > C_2H_5OH > CH_3OH$

(c) $C_2H_5OH > CH_3OH > (CH_3)_3COH > (CH_3)_2CHOH$

(d) There is no fixed order.

198. The ease of formation of the chlorides of $\overset{\circ}{1}, \overset{\circ}{2}$ and $\overset{\circ}{3}$ alcohols follows the order

(a) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3}$ (b) $\overset{\circ}{1} > \overset{\circ}{3} > \overset{\circ}{2}$ (c) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1}$ (d) $\overset{\circ}{1} = \overset{\circ}{2} = \overset{\circ}{3}$

199. Ethers react with concentrated H_2SO_4 to form

(a) zwitterions (b) an alkyl free radical

(c) oxyanions (d) oxonium ions

200. Compared to the dipole-dipole attraction between alcohol molecules, that between molecules of aldehydes and ketones is

(a) weak

(b) strong

(c) equal

(d) There is no dipole-dipole attraction between molecules of aldehydes and ketones.

201. In ketones, the reactivites of the carbonyl group of the compounds ethylmethyl ketone (I), diethyl ketone (II) and acetone (III), decrease in the order

(a) I > II > III (b) III > II > I

(c) I > III > II (d) III > I > II

202. The reactivities of the carbonyl compounds formaldehyde (I), acetaldehyde (II) and acetone (III) towards nucleophiles decrease in the order

(a) I > II > III (b) III > II > I

(c) II > I > III (d) III > I > II

203. The conversion of acetone into 2,3-dimethylbutane-2,3-diol can be achieved by

(a) using Zn/Hg/HCl (b) Wolff–Kishner reduction
(c) using Mg/Hg/H_2O (d) The conversion is not possible.

204. How many structures can compounds with the molecular formula $C_4H_8O_2$ have?

(a) Five (b) Four
(c) Three (d) Two

205. Arrange the following compounds in order of decreasing acidity.

$ClCH_2CH_2CH_2COOH$	$CH_3CHClCH_2COOH$	$CH_3CH_2CHClCOOH$
I	II	III

(a) I > II > III (b) III > II > I
(c) I > III > II (d) III > I > II

206. Arrange the following carboxylic acids in order of decreasing acidity.

Oxalic acid	Malonic acid	Succinic acid
I	II	III

(a) I > II > III (b) III > II > I
(c) I > III > II (d) II > III > I

207. Arrange $OHCH_2COOH$(I), $HOCH_2CH_2COOH$ (II) and CH_3COOH (III) in order of acidity.

(a) I > II > III (b) III > II > I
(c) I > III > II (d) II > III > I

208. The ease of hydrolysis with an alkali in the compounds

CH_3COCl	$CH_3CO–O–COCH_3$	$CH_3COOC_2H_5$	CH_3CONH_2
I	II	III	IV

is of the order

(a) I > II > III > IV (b) IV > III > II > I
(c) I > II > IV > III (d) II > I > IV > III

209. The reactivities of RCOX (I), RCOOCOR (II), R—COOR (III) and $RCONH_2$ (IV) with nucleophilic reagents follow the order

(a) I > II > III > IV (b) IV > III > II > I
(c) I > II > IV > III (d) II > I > IV > III

210. The boiling points of acetic anhydride (I), propionic anhydride (II) and butyric anhydride (III) follow the order

(a) I < II < III (b) III < II < I
(c) I < III < II (d) II < III < I

211. The reaction

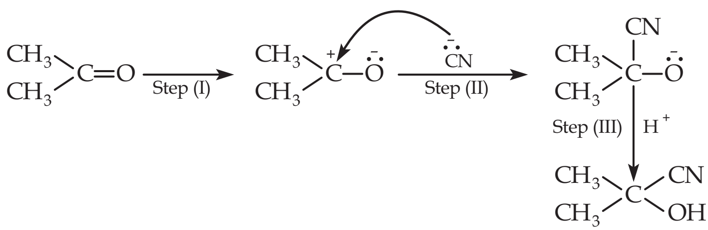
$$CH_3-\overset{\overset{\displaystyle O}{\|}}{C}-OC_2H_5 + n\text{–}C_3H_7OH \xrightarrow{n\text{-}C_3H_7ONa} CH_3COOC_3H_7(n) + C_2H_5OH$$

is known as

(a) esterification (b) double decomposition

(c) transesterification (d) none of these

212. The reaction of acetone with CN^- is represented as



In the above reaction, which is the fast step?

(a) Step (I)

(b) Step (II)

(c) Step (III)

(d) All the steps take place with equal ease.

213. The polarization

$$CH_2{=}CH{-}CH{=}CH{-}\underset{\underset{\displaystyle H}{|}}{C}{=}O \longleftrightarrow H_2\overset{+}{C}{-}CH{=}CH{-}CH{=}\underset{\underset{\displaystyle H}{|}}{C}{-}\overset{..}{\underset{..}{O}}{}^{-}$$

may be attributed to the

(a) inductive effect (b) electromeric effect

(c) mesomeric effect (d) hyperconjugative effect

214. Arrange CH_3CH_2OH (I), $(CH_3)_2CHOH$ (II) and $(CH_3)_3COH$ (III) in order of increasing acidity.

(a) I > II > III (b) III > II > I

(c) I > III > II (d) II > I > III

215. Arrange *p*-nitrophenol (I), *o*-nitrophenol (II), *m*-nitrophenol (III) and phenol (IV) in order of acidity.

(a) I > III > IV > II (b) I > II > III > IV

(c) IV > III > II > I (d) III > I > IV > II

216. Arrange 2,4,6-trinitrophenol (I); 2,4-dinitrophenol (II); *o*-nitrophenol (III) and *p*-nitrophenol (IV) in order of acidity.

(a) I > II > III = IV (b) IV > III > II > I

(c) I > II > IV > III (d) III > II > I > IV

217. Arrange phenol (I), *o*-cresol (II), *p*-cresol (III) and *m*-cresol (IV) in order of decreasing acid strength.

(a) I > IV > III > II (b) I > II > III > IV
(c) IV > III > II > I (d) II > I > IV > III

218. The rate of esterification of acetic acid with methyl alcohol (I), ethyl alcohol (II), isopropyl alcohol (III) and tert. butyl alcohol (IV) follows the order

(a) I > II > III > IV (b) IV > III > II > I
(c) II > I > IV > III (d) III > IV > I > II

219. The rate of esterification of HCOOH (I), CH_3COOH (II), $(CH_3)_2CHCOOH$ (III) and $(CH_3)_3CCOOH$ (IV) with ethanol follows the order

(a) IV > III > II > I (b) I > II > III > IV
(c) II > I > IV > III (d) III > IV > I > II

220. When phenol is heated with CCl_4 at 340 K, and this is followed by hydrolysis, the main product obtained is

(a) *o*-hydroxybenzaldehyde (b) *p*-hydroxybenzaldehyde
(c) *o*-hydroxybenzoic acid (d) *p*-hydroxybenzoic acid

221. Ethylene glycol, on being distilled with concentrated H_2SO_4, gives

(a) ethylene oxide (b) acetaldehyde
(c) 1,4-dioxane (d) diethylene glycol

222. Glycerol, on being heated with an excess of hydriodic acid, gives

(a) allyl iodide (b) isopropyl iodide
(c) acrolein (d) glyceraldehyde

223. The order of dehydration of $\overset{\circ}{1}$, $\overset{\circ}{2}$ and $\overset{\circ}{3}$ alcohols is

(a) $\overset{\circ}{1} > \overset{\circ}{2} > \overset{\circ}{3}$ (b) $\overset{\circ}{3} > \overset{\circ}{2} > \overset{\circ}{1}$ (c) $\overset{\circ}{2} > \overset{\circ}{1} > \overset{\circ}{3}$ (d) $\overset{\circ}{1} > \overset{\circ}{3} > \overset{\circ}{2}$

224. Arrange formaldehyde (I), acetaldehyde (II) and acetone (III) in order of reactivity towards nucleophilic addition.

(a) III > II > I (b) I > II > III
(c) II > I > III (d) III > I > II

225. Arrange $[(CH_3)_3C]_2CO$ (I), $[(CH_3)_2CH]_2C{=}O$ (II), $(CH_3)_2C{=}O$ (III) and CH_3CHO (IV) in order of reactivity towards nucleophilic attack.

(a) I > II > III > IV (b) I > III > IV > II
(c) IV > III > II > I (d) II > I > III > IV

226. $CH_3CH{=}CH{-}CHO$ may be reduced to $CH_3CH{=}CHCH_2OH$ using

(a) H_2/Pt (b) $NaBH_4$
(c) $[(CH_3)_2CHO]_3\,Al$ (d) Zn-Hg/HCl

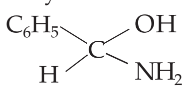
227. The reaction of benzaldehyde with excess of acetone in dilute NaOH at 273 K gives

(a) benzalacetophenone (b) benzalacetone
(c) dibenzalacetone (d) none of these

228. An organic compound reduces Tollens reagent and Fehling's solution. It can be

(a) CH_3CH_2CHO (b) C_6H_5CHO
(c) $CH_3COCH_2CH_3$ (d) $(CH_3)_3CCOCH_3$

229. Benzaldehyde reacts with ammonia to form

(a)  (b) $C_6H_5CH{=}NH$
(c) $(C_6H_5CH{=}N)_2\ CHC_6H_5$ (d) none of these

230. Treatment of acetophenone with bromine in ether at 273 K in the presence of a catalytic amount of aluminium trichloride gives

(a) *o*-bromoacetophenone (b) *m*-bromoacetophenone
(c) *p*-bromoacetophenone (d) phenacylbromide

231. Acetaldehyde, on being heated with concentrated H_2SO_4 at 273 K, gives

(a) acetic acid (b) paraldehyde
(c) metaldehyde (d) none of these

232. Arrange formic acid (I), benzoic acid (II), acetic acid (III) and phenylacetic acid (IV) in order of acidity.

(a) I > II > III > IV (b) IV > III > II > I
(c) I > II > IV > III (d) III > IV > II > I

233. Arrange *p*-nitrobenzoic acid (I), *p*-chlorobenzoic acid (II), benzoic acid (III), *p*-toluic acid (IV) and *p*-hydroxybenzoic acid (V) in order of decreasing acidity.

(a) I > II > IV > V > III (b) III > I > II > IV > V
(c) II > IV > I > III > V (d) I > II > III > IV > V

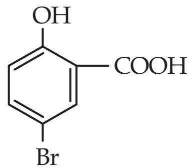
234. Arrange *o*-toluic acid (I), *m*-toluic acid (II), *p*-toluic acid (III) and benzoic acid (IV) in order of decreasing acid strength.

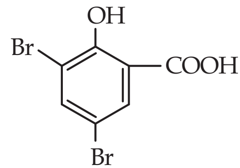
(a) I > II > III > IV (b) I > II > IV > III
(c) III > IV > I > II (d) I > IV > II > III

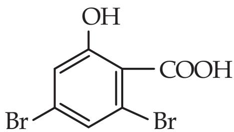
235. Arrange *o*-hydroxybenzoic acid (I), *m*-hydroxybenzoic acid (II), *p*-hydroxybenzoic acid (III) and benzoic acid (IV) in order of decreasing acid strength.

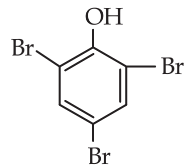
(a) I > II > IV > III (b) I > II > III > IV
(c) IV > III > II > I (d) II > III > I > IV

236. The bromination of salicylic acid with bromine water gives

(a) 

(b) 

(c) 

(d) 

• *Type 2* •

Choose the correct options. More than one option is correct.

237. The synthesis of

$$C_6H_5CH_2-\underset{\displaystyle OH}{\overset{\displaystyle CH_3}{\underset{|}{\overset{|}{C}}}}-CH_2-CH_3$$

can be achieved by

(a) $$CH_3CH_2\underset{\underset{\displaystyle O}{\|}}{C}CH_3 + C_6H_5CH_2MgCl \longrightarrow [\quad] \xrightarrow{H_2O}$$

(b) $$C_6H_5CH_2\underset{\underset{\displaystyle O}{\|}}{C}CH_3 + CH_3CH_2MgBr \longrightarrow [\quad] \xrightarrow{H_2O}$$

(c) $$C_6H_5CH_2\underset{\underset{\displaystyle O}{\|}}{C}CH_2CH_3 + CH_3MgI \longrightarrow [\quad] \xrightarrow{H_2O}$$

(d) none of these

238. Which of the following can be used for the synthesis of 2-methylbut-3-yne-2-ol?

(a) $HC\equiv CNa + CH_3-\overset{\overset{O}{\|}}{C}-CH_3$

(b) $HC\equiv CNa + CH_3-\overset{\overset{O}{\|}}{C}H$

(c) $HC\equiv CMgBr + CH_3-\overset{\overset{O}{\|}}{C}-CH_3$

(d) $HC\equiv CMgBr + CH_3-\overset{\overset{O}{\|}}{C}H$

239. Which of the following reactions will yield *p*-tert. butylphenol?

(a) phenol + $CH_3-\overset{\overset{CH_3}{|}}{C}=CH_2 \xrightarrow{H^+}$

(b) Phenol + $(CH_3)_3COH \xrightarrow{H^+}$

(c) Phenol + $(CH_3)_3CCl \xrightarrow{AlCl_3}$

(d) None of these

240. Which of the following reactions can be used to prepare

$$CH_3-\underset{\underset{C_2H_5}{|}}{\overset{\overset{OH}{|}}{C}}-C_6H_5$$

(a) $CH_3-\overset{\overset{O}{\|}}{C}-C_6H_5 + C_2H_5MgBr \longrightarrow [\quad] \xrightarrow{H_3O^+}$

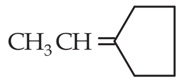
(b) $C_2H_5-\overset{\overset{O}{\|}}{C}-C_6H_5 + CH_3MgBr \longrightarrow [\quad] \xrightarrow{H_3O^+}$

(c) $CH_3-\overset{\overset{O}{\|}}{C}-C_2H_5 + C_6H_5MgBr \longrightarrow [\quad] \xrightarrow{H_3O^+}$

(d) $CH_3-\underset{\underset{C_2H_5}{|}}{\overset{\overset{Br}{|}}{C}}-C_6H_5 \xrightarrow[\Delta]{\text{alc. KOH}}$

241. Acetaldehyde is obtained in the reactions

(a) $CH_2{=}CH{-}CH_2{-}CH{=}CH_2 \xrightarrow[2.\ Zn,\ H_2O]{1.\ O_3}$

(b)  $\xrightarrow[2.\ Zn,\ H_2O]{1.\ O_3}$

(c) $HC{\equiv}CH + H_2O \xrightarrow[H_2SO_4]{HgSO_4}$

(d) $CH_3COCl + H_2 \xrightarrow{Pd{-}BaSO_4}$

242. Benzophenone can be obtained by

(a) $C_6H_6 + C_6H_5\overset{\overset{\large O}{\|}}{C}{-}Cl \xrightarrow{AlCl_3}$

(b) $(C_6H_5)_2CHOH \xrightarrow[H_2SO_4]{CrO_3}$

(c) $(C_6H_5)_2C{=}CH_2 \xrightarrow[2.\ Zn,\ H_2O]{1.\ O_3}$

(d) none of these

243. Which of the following can be used for the synthesis of benzyl acetate?

(a) $C_6H_5CH_2OH + (CH_3CO)_2O \longrightarrow$

(b) $C_6H_5CH_2OH + CH_3COOH \xrightarrow{H^+}$

(c) $C_6H_5CH_2OH + CH_3\overset{\overset{\large O}{\|}}{C}Cl \xrightarrow{base}$

(d) $C_6H_5CH_2OH + CH_3COOH \xrightarrow{NaOH}$

244. In which of the following reactions is benzoic acid the major product?

(a) $C_6H_5CH_2OH \xrightarrow[2.\ H_3O^+]{1.\ KMnO_4,\ OH^-}$

(b) $C_6H_5\overset{\overset{\large O}{\|}}{C}{-}CH_3 \xrightarrow[2.\ H_3O^+]{1.\ Cl_2,\ NaOH}$

(c) $C_6H_5MgBr \xrightarrow[2.\ H_3O^+]{1.\ CO_2}$

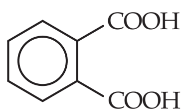
(d) $C_6H_5CH_3 \xrightarrow[2.\ H_3O^+]{1.\ KMnO_4,\ OH^-,\ \Delta}$

245. Acid anhydrides can be prepared by

(a) $C_6H_5COOH + CH_3COCl \xrightarrow{\text{pyridine}}$

(b) $C_6H_5COO^-Na^+ + C_6H_5COCl \longrightarrow$

(c) $CH_3CONH_2 + CH_3CO\bar{O}Na^+ \longrightarrow$

(d)  $\xrightarrow{\text{heat}}$

246. Which of the following will give cyclic products upon being heated or being treated by an acid.

(a) $CH_3\underset{OH}{\underset{|}{C}}HCH_2CH_2CH_2\overset{O}{\overset{\|}{C}}OH$

(b) $CH_3CH_2\underset{OH}{\underset{|}{C}}HCH_2CH_2\overset{O}{\overset{\|}{C}}OH$

(c) $CH_3CH_2CH_2\underset{OH}{\underset{|}{C}}HCH_2\overset{O}{\overset{\|}{C}}OH$

(d) $CH_3CH_2CH_2CH_2\underset{OH}{\underset{|}{C}}H\overset{O}{\overset{\|}{C}}OH$

247. Which of the following react to give the usual products?

(a) Di-tert. butyl ketone + methyl magnesium bromide

(b) Methyl isopropyl ketone + methyl magnesium bromide

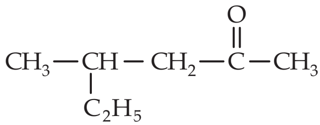
(c) Methyl isopropyl ketone + tert. butyl magnesium bromide

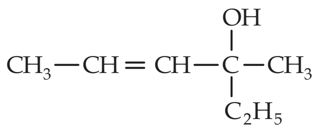
(d) Acetamide + methyl magnesium bromide

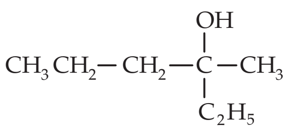
248. The product obtained in the reaction

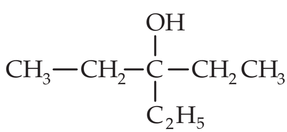
$$CH_3CH=CH-\overset{O}{\overset{\|}{C}}-CH_3 \xrightarrow[2.\ H_3O^+]{1.\ C_2H_5MgI}$$

is

(a) 

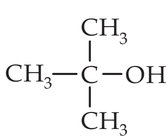
(b) 

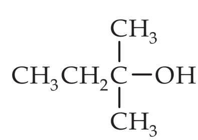
(c) 

(d) 

249. On treatment with a concentrated solution of zinc chloride in concentrated HCl at room temperature, an alcohol immediately gives, an oily product. The alcohol can be

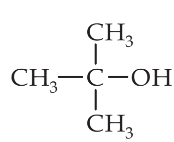
(a) $C_6H_5CH_2OH$ (b) $CH_3CHOHCH_3$

(c) 

(d) 

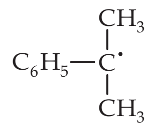
250. Which of the following alcohols can be oxidized by potassium dichromate in the presence of sulphuric acid?

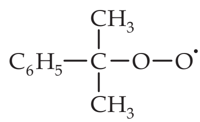
(a) CH_3CH_2OH (b) $C_6H_5CH_2OH$

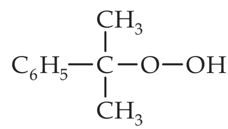
(c) $C_6H_5CHOHCH_3$ (d) 

251. The reaction of isopropylbenzene with oxygen in the presence of a catalytic amount of HBr followed by treatment with an acid gives phenol. The reaction proceeds through the intermediate formation of

(a) $HO\dot{O}$

(b) 

(c) 

(d) 

252. Which of the following statements are correct about a carbonyl group?

(a) The carbonyl carbon is sp^2-hybridized

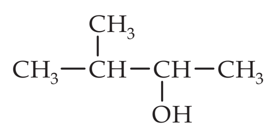
(b) The carbonyl carbon is sp^3-hybridized

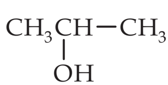
(c) The three groups attached to the carbonyl carbon lie in the same plane.

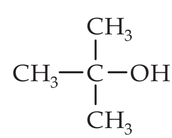
(d) The three groups attached to the carbonyl carbon lie in different planes.

253. On treatment with a clear solution of CrO_3 in dilute H_2SO_4, an aliphatic alcohol gives a greenish opaque solution within 2–3 seconds. The alcohol can be

(a) CH_3CH_2OH

(b) 

(c) 

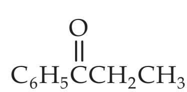
(d) 

254. The oxidation of which of the following compounds with hot alkaline $KMnO_4$ followed by treatment with an acid will give benzoic acid?

(a) $C_6H_5CH_3$

(b) $C_6H_5CH{=}CHCH_3$

(c) $C_6H_5C{\equiv}CCH_3$

(d) 

255. Which of the following statements are correct?

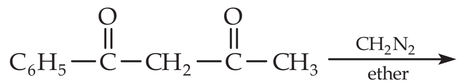
(a) *o*-Nitrophenol can be separated from *p*-nitrophenol because of intramolecular hydrogen bonding in *o*-nitrophenol.

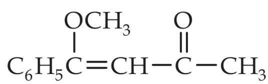
(b) *o*-Nitrophenol can be separated from *p*-nitrophenol because of intermolecular hydrogen bonding in *o*-nitrophenol.

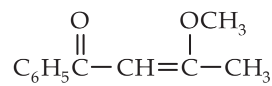
(c) *o*-Hydroxybenzoic acid can be separated from *p*-hydroxybenzoic acid because of intramolecular hydrogen bonding in *o*-hydroxybenzoic acid.

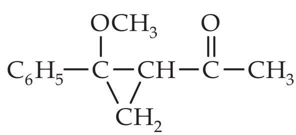
(d) *o*-Hydroxybenzoic acid can be separated from *p*-hydroxybenzoic acid because of intermolecular hydrogen bonding in *o*-hydroxybenzoic acid.

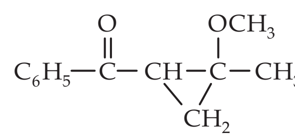
256. What are the products expected in the following reaction?



(a)


(b)


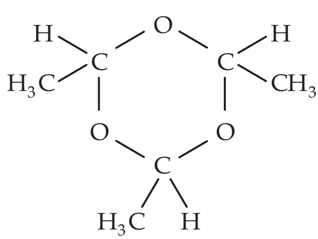
(c)


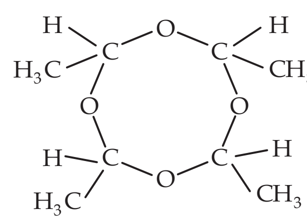
(d)


257. Under the influence of acids, acetaldehyde gives

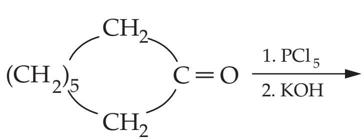
(a) $CH_3CH(OH)—CH_2CHO$

(b) $CH_3CH{=}CH—CHO$

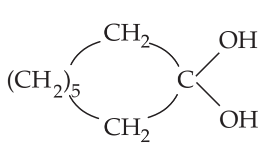
(c)


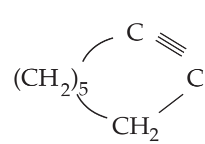
(d)


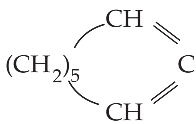
258. The final product of the reaction



is

(a)


(b)


(c) 

(d) The starting compound is recovered.

259. Which of the following carboxylic acids can be decarboxylated readily by heating them to 100–150°C?

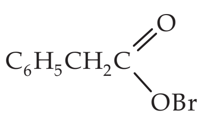
(a) CH_3COCH_2COOH (b) CCl_3COOH

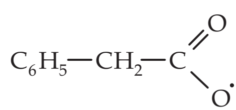
(c) $CH_2{=}CH{-}CH_2COOH$ (d) CH_3CH_2COOH

260. The intermediates formed during the reaction

$$C_6H_5CH_2CO_2Ag + Br_2 \xrightarrow[75°C]{\text{dry } CCl_4} C_6H_5CH_2Br$$

are

(a) 

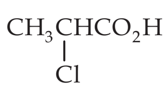
(b) 

(c) $C_6H_5\dot{C}H_2$ (d) $Br^{\bullet}$

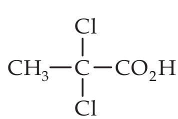
261. The products obtained in the reaction

$$CH_3CH_2CO_2H \xrightarrow{Cl_2,\, h\nu}$$

are

(a) 

(b) $ClCH_2CH_2CO_2H$

(c) 

(d) Cl_2CHCH_2COOH

262. Phosphorus pentachloride reacts with

(a) alcohols (b) ketones

(c) ethers (d) amines

263. Which of the following reactions are used in the preparation of alcohol?

(a) $C_2H_5Br + \text{aq. KOH} \longrightarrow$

(b) $(CH_3)_2C{=}O \xrightarrow{LiAlH_4}$

(c) $CH_3-\overset{\overset{\Large O}{\|}}{C}-OCH_3 \xrightarrow{Na/EtOH}$

(d) $CH_3CH_2Cl \xrightarrow{H_2O}$

264. Which of the following statements are not correct?

(a) All alcohols are soluble in water.

(b) Only the lower alcohols are soluble in water.

(c) All alcohols are poisonous.

(d) Methanol is not poisonous.

265. The reaction $2CH_3CH_2OH \xrightarrow[413\ K]{H^+} CH_3CH_2OCH_2CH_3$ is believed to occur through the formation of

(a) $CH_3CH_2\overset{+}{O}H_2$ (b) $CH_3\overset{+}{C}H_2$

(c) $CH_3CH_2-\underset{\underset{\Large H}{|}}{\overset{+}{\ddot{O}}}-CH_2CH_3$ (d) none of these

266. Which of the following are correct?

(a) Ordinary ethyl alcohol is known as rectified spirit.

(b) The alcohol sold in the market for polishing, etc., is known as methylated spirit.

(c) Absolute alcohol is 100% ethanol.

(d) Power alcohol is 100% ethanol.

267. Which of the following compounds are easily oxidized by $K_2Cr_2O_7$ and H_2SO_4?

(a) CH_3CH_2OH (b) $(CH_3)_2CHOH$

(c) CH_3CHO (d) $(CH_3)_3COH$

268. Which of the following exhibit hydrogen bonding?

(a) Chloroform (b) Ethyl alcohol

(c) Acetic acid (d) Dimethyl ether

269. Which of the following groups will increase the acidity of phenol?

(a) $-NO_2$ (b) $-CN$

(c) $-X$ (halogen) (d) None of these

270. Which of the following groups will increase the basicity of phenol?

(a) $-NH_2$ (b) $-CH_3$

(c) $-NO_2$ (d) None of these

271. Which of the following aldehydes undergo a Cannizzaro reaction?

(a) HCHO (b) C_6H_5CHO

(c) CH_3CHO (d) CH_3CH_2CHO

272. Which of the following aldehydes undergo aldol condensation?

(a) CH_3CHO (b) C_6H_5CHO

(c) $C_6H_5CH_2CHO$ (d) *p*-ClC_6H_4CHO

273. Which of the following are Cannizzaro reactions?

(a) $CH_3CHO + CH_3CHO \longrightarrow CH_3CH_2OH + HCOOH$

(b) $2Cl_3CCHO \longrightarrow Cl_3CCH_2OH + Cl_3CCOOH$

(c) $C_6H_5CHO + HCHO \longrightarrow C_6H_5CH_2OH + HCOOH$

(d) $C_6H_5CHO \longrightarrow C_6H_5CH_2OH + C_6H_5COOH$

274. Which of the following are aldol condensations?

(a) $CH_3CHO + CH_3CHO \xrightarrow{OH^-} CH_3CHOHCH_2CHO$

(b) $CH_3CHO + CH_3COCH_3 \xrightarrow{OH^-} CH_3CHOHCOCH_3$

(c) $HCHO + HCHO \xrightarrow{OH^-} CH_3OH + HCOONa$

(d) $C_6H_5CHO + C_6H_5CHO \xrightarrow{OH^-} C_6H_5CH_2OH + C_6H_5COONa$

275. Which of the following do not react with Fehling's solution?

(a) Benzaldehyde (b) Acetaldehyde

(c) Glucose (d) Acetophenone

276. Which of the following do not undergo base-catalysed aldol condensation?

(a) Benzaldehyde (b) 2,2-Dimethylpropionaldehyde

(c) 2-Methylpropionaldehyde (d) *p*-Methylbenzaldehyde

277. Which of the following statements are correct?

(a) When phenol vapour is passed over Zn dust, benzene is produced.

(b) The phenolic —OH group is ortho- and para-directing.

(c) *o*-Nitrophenol has a lower boiling point than *p*-nitrophenol.

(d) Phenol is more acidic than *o*-cresol.

278. Which of the following statements are correct?

(a) Benzaldehyde reduces Fehling's solution.

(b) $C_6H_5CHO + C_6H_5CHO \xrightarrow{NaOH} C_6H_5CH{=}CHC_6H_5 + O_2$ is a Claisen–Schmidt reaction.

(c) pK_a (formic acid) is less than pK_a (acetic acid).

(d) *o*-Toluidine is more basic than aniline.

279. Which of the following statements about ethers are correct?

(a) Peroxide is obtained in the presence of air.

(b) Ethers are weakly acidic.

(c) Ethers form oxonium salts.

(d) Ethers form stable complexes with Lewis acids.

280. Aldehydes can be reduced to hydrocarbons by

(a) the Clemmensen reduction

(b) the Wolff–Kishner reduction

(c) Mg/Hg, H_2O

(d) the Huang–Minlon method

281. Which of the following statements are correct about the C=O bond?

(a) It is made up of one π-bond and one σ-bond.

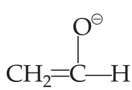
(b) It uses the sp^2-hybrid orbital of carbon for its formation.

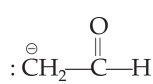
(c) It is planar in nature.

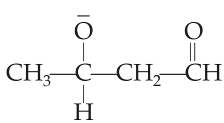
(d) It undergoes addition reactions.

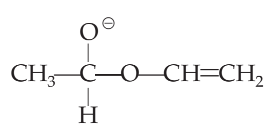
282. $CH_3—CHO \xrightarrow{\overset{\ominus}{O}H} CH_3CH(OH)CH_2CHO$

In the aldol condensation of acetaldehyde represented above, which of the following intermediate species are obtained?

(a) 

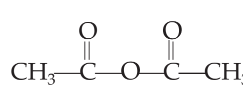
(b) 

(c) 

(d) 

283. Starting with $CH_2=C=O$, which of the following compounds can be obtained?

(a) CH_3COOH

(b) 

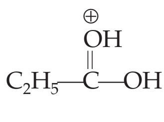
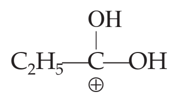
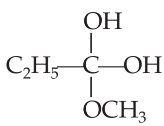
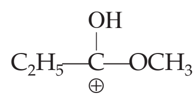
(c) 

(d) CH_3CONH_2

284. In the context of carboxylic acid (R—COOH), which of the following statements are correct?

(a) Hydrogen bonding is responsible for the high water solubility of simple aliphatic acids (C_1 to C_4).
(b) Carboxylic acids ionize in aqueous solutions by transferring protons to the solvent mlecules.
(c) Solubility decreases as chain length (R) increases.
(d) Solubility decreases with more branching in the chain (R).

285. In the esterification of propanoic acid with methanol in the presence of a mineral acid, which of the following are intermediate species?

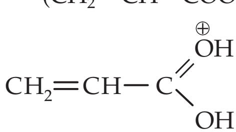
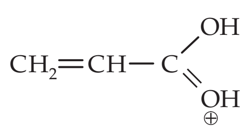
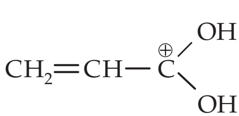
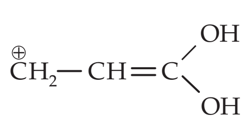
(a) 
(b) 
(c) 
(d) 

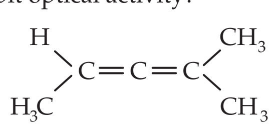
286. Which of the following methods are used for the conversion of carboxylic acids into acid chlorides ($RCOOH \longrightarrow RCOCl$)?
(a) $RCOOH + SOCl_2 \longrightarrow$
(b) $RCOOH + PCl_5 \longrightarrow$
(c) $RCOOH + Cl_2 \longrightarrow$
(d) $RCOOH + P + Cl_2 \longrightarrow$

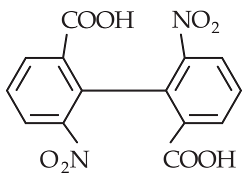
287. In which of the following esters is the α-hydrogen acidic?
(a) $CH_3COOC_2H_5$
(b) $O_2NCH_2COOC_2H_5$
(c) $NCCH_2COOC_2H_5$
(d) $CH_3COCH_2COOC_2H_5$

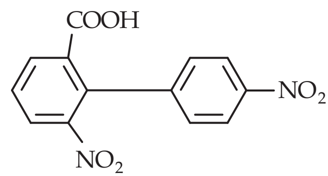
288. Which of the following intermediate species is/are formed in the reaction of acrylic acid with HBr to give β-bromopropionic acid

$$(CH_2{=}CH{-}COOH \xrightarrow{HBr} BrCH_2CH_2COOH)?$$

(a) 
(b) 
(c) 
(d) 

289. Which of the following compounds exhibit optical activity?
(a) $H_2C{=}C{=}CH_2$
(b) 

(c) 

(d) 

290. Which of the following will decolourize a $KMnO_4$ solution?

(a) CH_3CH_2OH (b) $CH_3CH{=}CH_2$

(c) $(CH_3)_2CHOH$ (d) CH_3COCH_3

291. Which of the following are protic solvents?

(a) Water (b) Ethanol

(c) Dimethylformamide (d) Dimethylsulphoxide

292. The intermediate stages in the conversion

$$(CH_3)_2\underset{\displaystyle OH}{\underset{|}{C}}-\underset{\displaystyle OH}{\underset{|}{C}}-(CH_3)_2 \xrightarrow[\Delta]{\text{dil. } H_2SO_4} CH_3COC(CH_3)_3 \text{ are}$$

(a) $(CH_3)_2-\underset{\displaystyle OH}{\underset{|}{C}}-\underset{\displaystyle \overset{}{OH_2}^{\oplus}}{\underset{|}{C}}(CH_3)_2$

(b) $(CH_3)_2-\underset{\displaystyle OH}{\underset{|}{C}}-\overset{\oplus}{C}(CH_3)_2$

(c) $CH_3-\underset{\displaystyle OH}{\underset{|}{\overset{\oplus}{C}}}-C(CH_3)_3$

(d) $CH_3-\underset{\displaystyle \overset{}{OH}^{\oplus}}{\underset{||}{C}}-C(CH_3)_3$

293. Which of the following compounds will give a red precipitate on being heated with Fehling's solution?

(a) C_6H_5CHO (b) CH_3CHO

(c) CH_3COCH_3 (d) $C_6H_5CH_2CHO$

294. What types of isomerism are exhibited by hexanoic acid?

(a) Chain isomerism (b) Position isomerism

(c) Functional group isomerism (d) Metamerism

295. Which of the following statements are correct?

(a) Carboxylic acids have higher boiling points than those of alcohols of similar molecular weight.

(b) Carboxylic acids have lower boiling points than those of alcohols of similar molecular weight.

(c) Carboxylic acids (C_1 to C_4) are soluble in water.

(d) The melting points of carboxylic acids increase or decrease in an irregular manner.

296. Which of the following statements are correct?

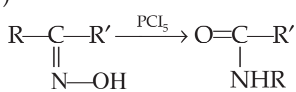
(a) The two carbon-oxygen bond lengths in formic acid are different.

(b) The two carbon-oxygen bond lengths in sodium formate are equal.

(c) The carbon-oxygen bond length in formic acid is less than that in sodium formate.

(d) The carbon-oxygen bond length in formic acid is greater than that in sodium formate.

297. In the context of the rearrangement of an oxime of a ketone to an amide (represented below)



which of the following statements are correct?

(a) It is the *trans*-hydrocarbon radical (R) with respect to the OH group that migrates.

(b) The group that migrates never gets completely detached from the remainder of the molecule during the transformation.

(c) The rearrangement is intermolecular.

(d) None of these

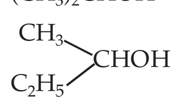
298. Nitration of phenol with dilute nitric acid at 293 K gives

(a) *o*-nitrophenol (b) *p*-nitrophenol

(c) *m*-nitrophenol (d) 2,4,6-nitrophenol

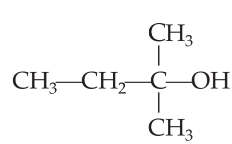
299. An alcohol, on treatment with $P + I_2$ followed by the reaction of the formed product first with $AgNO_2$ and then with HNO_2 and final basicification, gives a blue colour. Which of the following alcohols can it be?

(a) CH_3CH_2OH (b) $(CH_3)_2CHOH$

(c) $(CH_3)_3C—OH$ (d) 

300. Which of the following alcohols, on treatment with concentrated HCl and anhydrous $ZnCl_2$, will become turbid instantaneously?

(a) CH_3OH (b) $(CH_3)_2CHOH$

(c) $(CH_3)_3COH$ (d) 

301. Which of the following compounds will react positively to the iodoform test?

(a) $(CH_3)_2CHOH$ (b) CH_3CH_2OH

(c) $CH_3CH_2CH_2OH$ (d) $CH_3CHOHCH_2CH_3$

302. The reaction of glycerol with HIO_4 gives

(a) formaldehyde (b) formic acid

(c) iodic acid (d) oxalic acid

303. Glycerol, on being heated with oxalic acid at 383 K, gives

(a) glyceryl monooxalate

(b) glyceryl monoformate

(c) allyl alcohol

(d) formic acid

304. Which of the following will result in the formation of an ether?

(a) $(CH_3)_3C\overset{-}{O}\overset{+}{N}a + CH_3CH_2Br \longrightarrow$

(b) $(CH_3)_3CBr + C_2H_5\overset{-}{O}\overset{+}{N}a \longrightarrow$

(c) $C_6H_5ONa + CH_3Br \longrightarrow$

(d) $C_6H_5Br + CH_3\overset{-}{O}\overset{+}{N}a \longrightarrow$

305. Methylethyl ketone can be reduced to *n*-butane by

(a) the Meerwein–Ponndorf reduction

(b) the Wolff–Kishner reduction

(c) Mg-Hg, H_2O

(d) HI/red phosphorus at 423 K

306. On being treated with HCl, acetone gives

(a) mesityl oxide (b) phorone

(c) mesitylene (d) aldol

307. Which of the following statements are correct for benzoic acid?

(a) Nitration gives *o*- and *p*-nitrobenzoic acid.

(b) Bromination ($Br_2/FeBr_3$) gives *m*-bromobenzoic acid.

(c) The Friedel–Crafts reaction with $CH_3COCl/AlCl_3$ gives *m*-carboxyacetophenone.

(d) The reaction with concentrated sulphuric acid gives 3-carboxybenzenesulphonic acid.

Answers

1. c	**2.** b	**3.** a	**4.** b	**5.** d
6. a	**7.** b	**8.** b	**9.** a	**10.** c
11. b	**12.** a	**13.** c	**14.** a	**15.** c
16. b	**17.** d	**18.** a	**19.** c	**20.** c
21. c	**22.** d	**23.** a	**24.** b	**25.** c
26. b	**27.** a	**28.** c	**29.** d	**30.** d
31. b	**32.** c	**33.** a	**34.** c	**35.** a
36. c	**37.** c	**38.** b	**39.** b	**40.** a
41. c	**42.** a	**43.** a	**44.** c	**45.** b
46. a	**47.** c	**48.** a	**49.** c	**50.** a
51. a	**52.** c	**53.** c	**54.** d	**55.** c
56. d	**57.** a	**58.** a	**59.** b	**60.** a
61. a	**62.** c	**63.** a	**64.** a	**65.** a
66. a	**67.** a	**68.** a	**69.** c	**70.** d
71. c	**72.** d	**73.** b	**74.** b	**75.** a
76. a	**77.** a	**78.** d	**79.** c	**80.** d
81. c	**82.** a	**83.** d	**84.** a	**85.** b
86. b	**87.** b	**88.** b	**89.** c	**90.** d
91. c	**92.** c	**93.** a	**94.** b	**95.** d
96. b	**97.** c	**98.** c	**99.** c	**100.** a
101. b	**102.** a	**103.** a	**104.** b	**105.** c
106. b	**107.** a	**108.** c	**109.** a	**110.** a
111. b	**112.** d	**113.** a	**114.** c	**115.** a
116. a	**117.** a	**118.** a	**119.** a	**120.** a
121. b	**122.** b	**123.** a	**124.** b	**125.** d
126. b	**127.** b	**128.** a	**129.** a	**130.** c
131. d	**132.** b	**133.** d	**134.** a	**135.** b
136. c	**137.** d	**138.** b	**139.** b	**140.** d
141. b	**142.** b	**143.** b	**144.** c	**145.** c
146. c	**147.** c	**148.** a	**149.** a	**150.** a
151. a	**152.** b	**153.** c	**154.** c	**155.** a
156. d	**157.** b	**158.** b	**159.** d	**160.** d
161. a	**162.** c	**163.** b	**164.** c	**165.** d
166. c	**167.** b	**168.** a	**169.** a	**170.** b
171. c	**172.** a	**173.** d	**174.** a	**175.** a
176. c	**177.** b	**178.** a	**179.** a	**180.** c
181. a	**182.** b	**183.** a	**184.** a	**185.** c
186. a	**187.** c	**188.** a	**189.** a	**190.** c

191. d	**192.** a	**193.** a	**194.** a	**195.** a
196. c	**197.** a	**198.** c	**199.** d	**200.** a
201. d	**202.** a	**203.** c	**204.** b	**205.** b
206. a	**207.** a	**208.** a	**209.** a	**210.** b
211. c	**212.** c	**213.** c	**214.** a	**215.** b
216. c	**217.** a	**218.** a	**219.** b	**220.** c
221. c	**222.** b	**223.** b	**224.** b	**225.** c
226. b	**227.** b	**228.** a	**229.** c	**230.** d
231. c	**232.** c	**233.** d	**234.** d	**235.** a
236. d	**237.** a, b, c	**238.** a, c	**239.** a, b, c	**240.** a, b, c
241. b, c, d	**242.** a, b, c	**243.** a, b, c	**244.** a, b, c, d	**245.** a, b, d
246. a, b, d	**247.** b, d	**248.** a, b	**249.** c, d	**250.** a, b, c
251. a, b, c, d	**252.** a, c	**253.** a, b, c	**254.** a, b, c, d	**255.** a, c
256. a, b	**257.** c, d	**258.** b, c	**259.** a, b	**260.** a, b, c, d
261. a, b	**262.** a, b, c	**263.** a, b, c	**264.** a, c	**265.** a, b, c
266. a, b, c	**267.** a, b, c	**268.** b, c, d	**269.** a, b, c	**270.** a, b
271. a, b	**272.** a, c	**273.** b, c, d	**274.** a, b	**275.** a, d
276. a, b, d	**277.** a, b, c, d	**278.** c, d	**279.** a, c, d	**280.** a, b, d
281. a, b, c, d	**282.** a, b, c	**283.** a, b, c	**284.** a, b, c, d	**285.** a, b, c, d
286. a, b, d	**287.** a, b, c, d	**288.** a, b, c, d	**289.** b, c	**290.** a, b, c
291. a, b	**292.** a, b, c, d	**293.** b, d	**294.** a, b	**295.** a, c, d
296. a, b, c	**297.** a, b	**298.** a, b	**299.** b, d	**300.** c, d
301. a, b, d	**302.** a, b, c	**303.** a, b	**304.** a, c	**305.** b, d
306. a, b	**307.** b, d			

Hints to More Difficult Problems

35. The more stable a carbonyl compound is, the more easily does it hydrogenate catalytically.

42. The acid strengths of phenols and carboxylic acids depend on their pK_a values.

44. Unlike other aliphatic aldehydes, formaldehyde reacts with ammonia to form hexamethylenetetramine, a cyclic compound. Upon nitration, this gives a trinitro-derivative—an explosive cyclonite also called RDX.

45. On reaction with HCN in the presence of an alkali, α,β-unsaturated ketones do not give the expected cyanohydrins. In this case, 1,4-addition results in the formation of a β-cyanoketone.

46. The addition of HCl to α,β-unsaturated aldehydes and ketones moves the halogen to the β-carbon. However, if there is a vinyl group in conjugation with the carbonyl group, the position is opposite to that expected from Markovnikov's rule.

47. Simple aldehydes undergo normal Cannizzaro reactions but compounds containing two aldehyde groups undergo internal Cannizzaro reactions, i.e., one CHO is oxidized while the other CHO is reduced.

48. On treatment of carboxylic acids with Cl_2/P, Cl gets attached to the α-carbon since it is more reactive.

49. The first step is the formation of

$$BrCH_2—\underset{\displaystyle OH}{\underset{|}{C}H}—CH_2CH_2CO_2H.$$

Being a γ-hydroxyacid, it undergoes lactonization to give the product shown in option (c).

247. The reaction of a ketone and a Grignard reagent does not yield the usual products in the following cases.

(a) The branching of the carbon chain near the carbonyl group prevents nucleophilic addition by the Grignard reagent due to steric hindrance.

(b) If the Grignard reagent has a bulky alkyl or aryl group, it fails to attack the electrophilic centre of the substrate molecule.

248. Products are obtained from α,β-unsaturated aldehydes and ketones respectively through the initial 1,4- and 1,2-additions.

253. On treatment with a solution of CrO_3 in dilute H_2SO_4, primary and secondary alcohols become greenish and opaque within 2–3 seconds.

258. The gem dihalide obtained initially from the carbonyl compound undergoes an E2-type elimination to give allenes and acetylenes.

259. Thermal decarboxylation occurs most readily when the α-carbon atom attached to the —COOH group carries a strongly electron-withdrawing group (i.e., –I substituent).

260. The decarboxylation of the silver salts of carboxylic acids in the presence of bromine or chlorine is called a Hunsdiecker reaction and is useful for the synthesis of alkyl halides.

261. In the presence of UV light, the reaction of chlorine with $CH_3CH_2CO_2H$ involves the free-radical chlorination at all positions along the chain. This is also true of all hydrocarbons.

❑

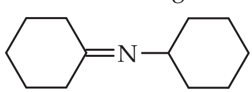
7

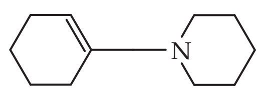
Compounds Containing Nitrogen and Sulphur

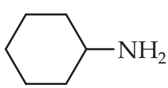
• *Type 1* •

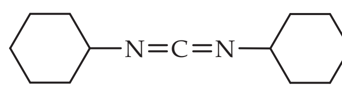
Choose the correct option. Only one option is correct.

1. Which of the following is an enamine?

(a) 

(b) 

(c) 

(d) 

2. What type of amine is tertiary butylamine?

(a) Primary (b) Secondary (c) Tertiary (d) Quaternary

3. Which reagent is used to distinguish between $(C_2H_5)_2NH$ and $(C_2H_5)_3N$?

(a) NaOH (b) Dilute HCl (c) $C_6H_5SO_2Cl$ (d) $KMnO_4$

4. A molecule of which of the following will exhibit hydrogen bonding with another of the same compound?

(a) $\begin{array}{c} CH_3-\ddot{N}-CH_3 \\ | \\ CH_3 \end{array}$

(b) $CH_3\ddot{N}H_2$

(c) CF_3CH_3

(d) $CH_3-\ddot{\underset{..}{O}}-CH_3$

5. N,N-Dimethylbenzamide cannot be made by

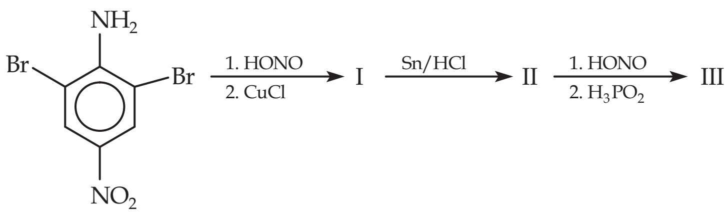
(a) $$C_6H_5\overset{\overset{\displaystyle O}{\|}}{C}OC_2H_5 + (CH_3)_2NH \longrightarrow$$

(b) $$C_6H_5\overset{\displaystyle O}{\overset{\|}{C}}Cl + (CH_3)_2NH \longrightarrow$$

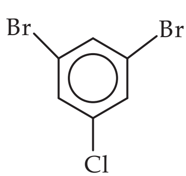
(c) $$C_6H_5\overset{\displaystyle O}{\overset{\|}{C}}-O-\overset{\displaystyle O}{\overset{\|}{C}}C_6H_5 + (CH_3)_2NH \longrightarrow$$

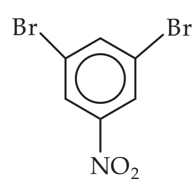
(d) $$C_6H_5\overset{\displaystyle O}{\overset{\|}{C}}NH_2 + CH_3MgCl \longrightarrow$$

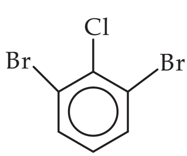
6. The final product (III) obtained in the reaction sequence



is

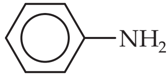
(a) 

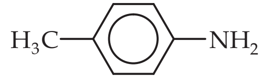
(b) 

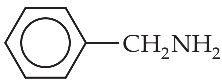
(c) 

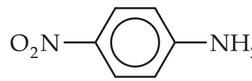
(d) none of these

7. Among the following, which is the strongest base?

(a) 

(b) 

(c) 

(d) 

8. Which of the following reactions can be used to synthesise *m*-bromoaniline?

(a) $C_6H_6 \xrightarrow[\text{2. Sn + HCl}]{\text{1. HNO}_3/\text{H}_2\text{SO}_4} [\quad] \xrightarrow{Br_2/H_2O}$

(b) $C_6H_6 \xrightarrow[\text{2. } HNO_3/H_2SO_4]{\text{1. } Br_2/FeBr_3} [\quad] \xrightarrow[Pt]{H_2}$

(c) $C_6H_5COOH \xrightarrow[FeCl_3]{Br} [\quad] \xrightarrow[\text{2. } NH_3]{\text{1. } SOCl_2} [\quad] \xrightarrow[NaOH]{Br_2}$

(d) None of these

9. Which of the following reagents will be useful as the basis for a simple chemical test to distinguish between

(a) $C_6H_5SO_2Cl$ and OH^- in H_2O (b) HONO, then β-naphthol

(c) Dilute HCl (d) $AgNO_3$ in H_2O

10. 3,5-Dibromotoluene can be best synthesised by

(a) Toluene $\xrightarrow{Br_2/Fe/\text{heat}}$

(b) *p*-Toluidine $\xrightarrow{Br_2,\ H_2O} [\quad] \xrightarrow[\text{2. } H_3PO_2]{\text{1. } HNO_2}$

(c) Toluene $\xrightarrow[\text{fuming } H_2SO_4]{\text{fuming } HNO_3} [\quad] \xrightarrow{NH_3} [\quad] \xrightarrow[\text{2. CuBr}]{\text{1. HCNO}}$

(d) 1,3-Dibromotoluene $\xrightarrow{CH_3Cl/AlCl_3/\text{heat}}$

11. The final product (IV) obtained in the reaction sequence

$$\text{Toluene} \xrightarrow[\text{2. } H^+]{\text{1. } KMnO_4/OH^-} \text{I} \xrightarrow{SOCl_2} \text{II} \xrightarrow{NH_3} \text{III} \xrightarrow{OBr^-} \text{IV}$$

is

(a) $C_6H_5CONH_2$ (b) *p*-$CH_3C_6H_4NO_2$

(c) $C_6H_5CH_2NH_2$ (d) $C_6H_5NH_2$

12. Among the following, which is the strongest base?

(a)
$$CH_3-\underset{\underset{\displaystyle CH_3}{|}}{\overset{\overset{\displaystyle CH_3}{|}}{C}}-NH_2$$

(b)
$$CH_3\overset{\overset{\displaystyle H}{|}}{N}CH_3$$

(c) $CH_3-\underset{\underset{CH_3}{|}}{N}-CH_3$ (d) $CH_3\overset{\overset{O}{\|}}{C}-N\begin{matrix}\nearrow CH_3\\ \searrow CH_3\end{matrix}$

13. The best method to synthesise *m*-dibromobenzene is by using the reaction

(a) $\text{Benzene} \xrightarrow{Br_2/FeBr_3/\text{heat}}$

(b) $\text{Aniline} \xrightarrow{Br_2,\ H_2O} [\quad] \xrightarrow[\text{2. CuBr}]{\text{1. HONO}}$

(c) $\text{Nitrobenzene} \xrightarrow[H_2SO_4,\ \Delta]{\text{fuming } HNO_3} [\quad] \xrightarrow[C_2H_5OH,\ \text{heat}]{Fe/HCl} [\quad] \xrightarrow[\text{2. CuBr}]{\text{1. HONO}}$

(d) $\text{Bromobenzene} \xrightarrow[H_2SO_4]{HNO_3} [\quad] \xrightarrow[C_2H_5OH,\ \text{heat}]{Fe/HCl} [\quad] \xrightarrow[\text{2. CuBr}]{\text{1. HONO}}$

14. *m*-Fluoronitrobenzene is best synthesised by using the reaction

(a) $\text{Nitrobenzene} \xrightarrow[H_2SO_4,\ \text{heat}]{\text{fuming } HNO_3} [\quad] \xrightarrow{NH_3/H_2S} [\quad] \xrightarrow[\text{2. } HBF_4,\ \Delta]{\text{1. HONO}}$

(b) $\text{Aniline} \xrightarrow[\text{heat}]{F_2}$

(c) $\text{Fluorobenzene} \xrightarrow[H_2SO_4,\ \text{heat}]{HNO_3}$

(d) $m\text{-}C_6H_4(NH_2)_2 \xrightarrow[\text{2. } CuNO_2,\ \text{3. } HBF_4]{\text{1. HONO}}$

15. The final product obtained in the reaction

$$C_6H_5NH_2 + HONO \xrightarrow[\text{2. heat}]{\text{1. HCl(0–5°C)}}$$

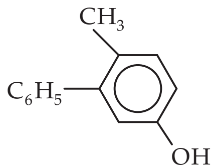
is

(a) C_6H_5Cl (b) C_6H_5OH (c) C_6H_6 (d) none of these

16. The major product obtained in the reaction

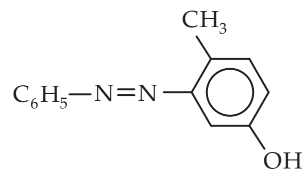
$$C_6H_5NH_2 + NaNO_2 + HCl \xrightarrow{0\text{–}5°C} [\quad] \xrightarrow[NaOH]{p\text{–}CH_3C_6H_4OH}$$

is

(a) 

(b) C_6H_5OH

(c) $C_6H_5NO_2$

(d) 

17. Which of the following is a thioether?

(a) $CH_3\overset{\overset{\displaystyle O}{\|}}{S}CH_3$

(b) $CH_3—S—S—CH_3$

(c) $CH_3CH_2SCH_2CH_3$

(d) None of these

18. The transformation $C_6H_5CH_2CH_2Br \longrightarrow C_6H_5CH_2CH_2SH$ can be effected using

(a) H_2S

(b) $NH_2\underset{\underset{\displaystyle S}{\|}}{C}NH_2$

(c) $CH_3\underset{\underset{\displaystyle O}{\|}}{S}\overset{-}{C}H_2\overset{+}{Na}$

(d) NaSH

19. The transformation

$$CH_3CH_2I \longrightarrow CH_3CH_2SCH_2CH_3$$

can be effected by

(a) K_2S, Δ

(b) P_2S_5/Δ

(c) H_2S

(d) $NH_2\underset{\underset{\displaystyle S}{\|}}{C}NH_2$

20. Which of the following statements is correct?

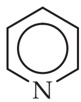
(a) Methylamine is more basic than ammonia.

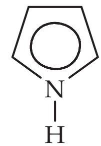
(b) Dimethyl amine is less basic than methylamine.

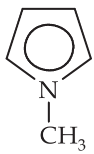
(c) Dimethylamine is less basic than trimethylamine

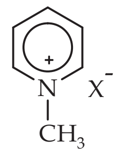
(d) Ammonia is more basic than methylamine

21. Which of the following compounds is the most reactive to a nucleophilic attack?

(a) 

(b) 

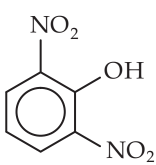
(c) 

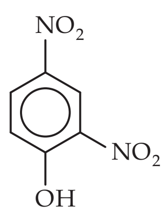
(d) 

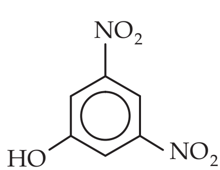
22. In the reaction of (S) 2-phenylpropamide with NaOBr/H_2O to give 1-phenylethylamine,

(a) there is retention of configuration
(b) there is inversion of configuration
(c) a mixture of two products is obtained
(d) there is no reaction

23. The oxidation of *m*-dinitrobenzene with alkaline potassium ferricyanide gives

(a) 

(b) 

(c) 

(d) There is no reaction.

24. Nitrobenzene can be converted into phenylhydroxylamine by reduction with

(a) Zn–NH_4Cl–H_2O (b) alkaline sodium arsenite
(c) alkaline sodium stannite (d) Zn–aqueous NaOH

25. In pyridine, the state of hybridization of the nitrogen atom is

(a) sp^2 (b) sp^3
(c) sp (d) none of these

26. The final product (III) obtained in the reaction

$$CH_3CH_2NH_2 \xrightarrow[NaOH]{CH_3COCl} I \xrightarrow{HONO} II \xrightarrow{\Delta} III$$

is

(a) $CH_3CH_2O\overset{\overset{\displaystyle O}{\|}}{C}CH_3$

(b) CH_3CH_2OH

(c) $CH_3O\overset{\overset{\displaystyle O}{\|}}{C}CH_2CH_3$

(d) none of these

27. The product obtained in the reaction

$$C_6H_5N{=}C\colon + CH_3\overset{\overset{\displaystyle O}{\|}}{C}CH_3 + CH_3CO_2H \longrightarrow$$

is

(a) $C_6H_5NH_2$

(b) C_6H_5COOH

(c) $C_6H_5NHC_6H_5$

(d) $C_6H_5\overset{\overset{\displaystyle H}{|}}{N}-\overset{\overset{\displaystyle O}{\|}}{C}-\underset{\underset{\displaystyle CH_3}{|}}{\overset{\overset{\displaystyle CH_3}{|}}{C}}-O-\overset{\overset{\displaystyle O}{\|}}{C}-CH_3$

28. The product obtained in the reaction

$$\underset{\underset{\displaystyle CH_3}{|}}{\overset{\overset{\displaystyle CH_3}{|}}{HC}}-NO_2 + CH_2{=}CH-C{\equiv}N \xrightarrow[30°C]{\bar{O}H}$$

is

(a) $N{\equiv}C-CH_2CH_2-\underset{\underset{\displaystyle CH_3}{|}}{\overset{\overset{\displaystyle CH_3}{|}}{C}}-NO_2$

(b) $N{\equiv}C-CH_2-CH_2-\underset{\underset{\displaystyle CH_3}{|}}{\overset{\overset{\displaystyle CH_3}{|}}{C}}-NH_2$

(c)

$$\begin{array}{c} \qquad\qquad\qquad\qquad\qquad CH_3 \\ \qquad\qquad\qquad\qquad\qquad | \\ N{\equiv}C{-}CH_2CH_2{-}C{-}NO_2 \\ \qquad\qquad\qquad\qquad\qquad | \\ \qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad CH_2CH_2CH_2C{\equiv}N \end{array}$$

(d)

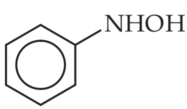
$$\begin{array}{c} \qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad CH_2CH_2CH_2C{\equiv}N \\ \qquad\qquad\qquad\qquad\qquad | \\ N{\equiv}C{-}CH_2{-}CH_2{-}C{-}NO_2 \\ \qquad\qquad\qquad\qquad\qquad | \\ \qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad CH_2CH_2CH_2C{\equiv}N \end{array}$$

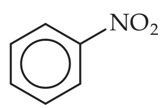
29. Which of the following species is present in a solution of glycine (H_2NCH_2COOH)?

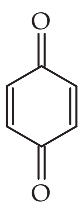
(a) $H_3\overset{+}{N}CH_2CO_2H$ (b) $\overset{+}{N}H_3CH_2\overset{-}{CO_2}$

(c) $NH_2CH_2\overset{-}{CO_2}$ (d) All of these

30. The oxidation of aniline with peracetic acid in the presence of acetic acid by refluxing gives

(a) 

(b) 

(c) 

(d) none of these

31. The final product of the reaction of ethyl bromide with H_2S in the presence of KOH,

$$CH_3CH_2Br + KOH + H_2S \xrightarrow[\text{heat}]{C_2H_5OH}$$

is

(a) CH_3CH_2SH (b) $CH_3CH_2SCH_2CH_3$

(c) $CH_3CH_2S{-}S{-}CH_2CH_3$ (d) none of these

32. Which of the following amines is chiral?

(a) $CH_3CH_2CH_2NH_2$ (b) $CH_3CH_2NH{-}CH_3$

(c) $\begin{array}{c} \qquad\quad CH_3 \\ \qquad | \\ CH_3{-}N{:} \\ \qquad | \\ \qquad\quad CH_3 \end{array}$ (d) $\begin{array}{c} \qquad\quad C_2H_5 \\ \qquad | \\ CH_3{-}N{:} \\ \qquad | \\ \qquad\quad C_3H_7 \end{array}$

33. In an aqueous solution, the order of basicity of the amines $(CH_3)_3N$, $(CH_3)_2NH$, CH_3NH_2 and NH_3 is

(a) $(CH_3)_3N > (CH_3)_2NH > CH_3NH_2 > NH_3$

(b) $(CH_3)_2NH > CH_3NH_2 > CH_3N > NH_3$

(c) $NH_3 > CH_3NH_2 > (CH_3)_2NH > (CH_3)_3N$

(d) All these amines are equally basic.

34. The order of basicity of the amines $(CH_3)_3N$, $(CH_3)_2NH$, CH_3NH_2 and NH_3 in the gaseous phase is

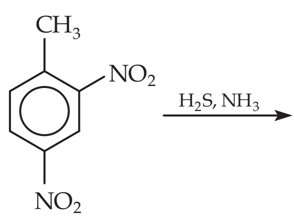
(a) $(CH_3)_3N > (CH_3)_2NH > CH_3NH_2 > NH_3$

(b) $NH_3 > CH_3NH_2 > (CH_3)_2NH > (CH_3)_3N$

(c) $(CH_3)_2NH > CH_3NH_2 > (CH_3)_3N > NH_3$

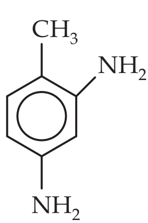
(d) All these amines are equally basic.

35. The product obtained in the reduction

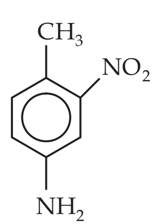


is

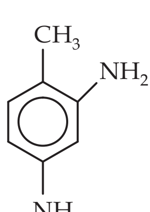
(a)



(b)

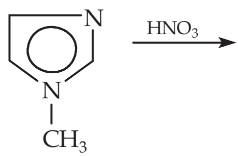


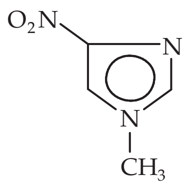
(c)

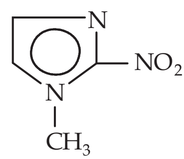


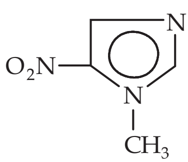
(d) The compound is not reduced.

36. The product obtained in the reaction



(a) 

(b) 

(c) 

(d) There is no reaction.

37. The reaction of dimethylsulphoxide with α-bromoacetophenone ($C_6H_5COCH_2Br$) gives

(a) $C_6H_5COCH_2OH$ (b) C_6H_5COCHO

(c) $C_6H_5COCOOH$ (d) No reaction takes place.

38. In the conversion $C_2H_5Br \longrightarrow C_2H_5CN$, the reagent used is

(a) alcoholic KCN (b) alcoholic AgCN

(c) NH_3 (d) none of these

39. The reduction of methyl cyanide with sodium and alcohol gives

(a) methylamine (b) ethylamine

(c) acetic acid (d) methyl alcohol

40. An aliphatic organic compound containing C, H and N reacts with dilute HCl to produce formic acid. It is reduced to dimethylamine by Pt or Ni, and undergoes an addition reaction with chlorine and sulphur. The compound can be

(a) CH_3NC (b) CH_3CN

(c) CH_3NH_2 (d) a mixture of (a) and (b)

41. Ethyl isocyanide is prepared by the reaction between

(a) C_2H_5Br and KCN (b) C_2H_5Br and AgCN

(c) C_2H_5Br and HCN (d) C_2H_5Br and NH_3

42. In the reaction between C_2H_5Br and alcoholic $AgNO_2$, the product obtained is

(a) nitroethane (b) ethane
(c) ethyl nitrite (d) ethyl isocyanide

43. In the reaction between CH_3NC and HgO, the product obtained is

(a) methyl isothiocyanate (b) methyl isocyanate
(c) methylamine (d) methyl cyanide

44. Which of the following reactions will produce methyl nitrite as the major product?

(a) $CH_3I + AgNO_2 \longrightarrow$ (b) $CH_3I + NaNO_2 \longrightarrow$
(c) both (a) and (b) (d) neither

45. An organic amino compound reacts with aqueous nitrous acid at low temperature to produce an oily nitrosoamine. The compound is

(a) CH_3NH_2 (b) $CH_3CH_2NH_2$
(c) $(C_2H_5)_2NH$ (d) $(C_2H_5)_3N$

46. In the nitration of benzene with concentrated HNO_3 and concentrated H_2SO_4, the electrophile is

(a) NO_2^+ (b) NO_2^-
(c) NO_2 (d) nitric oxide

47. A nitroalkane reacts with nitrous acid to yield a product which is insoluble in an alkali, and turns blue on treatment with an alkali. The nitroalkane could be

(a) $CH_3CH_2NO_2$ (b) $(CH_3)_2CHNO_2$
(c) $(CH_3)_3CNO_2$ (d) $CH_3\underset{\displaystyle CH_3}{\underset{|}{C}H}—CH_2NO_2$

48. A nitroalkane produces a ketone when it is boiled with HCl. The nitroalkane could be

(a) $CH_3CH_2NO_2$ (b) $(CH_3)_2CHNO_2$
(c) $(CH_3)_3CNO_2$ (d) $CH_3—\overset{\displaystyle CH_3}{\overset{|}{\underset{\displaystyle CH_3}{\underset{|}{C}}}}—CH_2NO_2$

49. The electrolytic reduction of nitrobenzene in a strongly acidic medium produces

(a) aniline (b) azoxybenzene
(c) *p*-aminophenol (d) azobenzene

50. The electrolytic reduction of nitrobenzene in a weakly acidic medium produces

(a) aniline (b) phenylhydroxylamine
(c) *p*-aminophenol (d) azoxybenzene

51. Which of the following will give only one monosubstituted product?

(a) *o*-Dinitrobenzene (b) *m*-Dinitrobenzene
(c) *p*-Dinitrobenzene (d) None of these

52. The oxidation of aniline with $K_2Cr_2O_7/H_2SO_4$ produces

(a) benzoic acid (b) benzene
(c) *p*-benzoquinone (d) *p*-nitrophenol

53. How many isomeric amines with the formula C_7H_9N contain a benzene ring?

(a) Two (b) Three
(c) Four (d) Five

54. How many isomeric amines can have the formula $C_4H_{11}N$?

(a) Five (b) Six
(c) Seven (d) Eight

55. Which among the following has the highest boiling point?

(a) $CH_3CH_2CH_2NH_2$ (b) $CH_3CH_2{-}\underset{\displaystyle CH_3}{\underset{|}{NH}}$

(c) $CH_3{-}\overset{\displaystyle CH_3}{\overset{|}{N}}{-}CH_3$ (d) CH_3NH_2

56. The N atom in amines involves

(a) sp^3 hybridization (b) sp^2 hybridization
(c) sp^2 and sp^3 hybridization (d) none of these

57. Arrange the following in order of decreasing basic strength.
$(C_2H_5)_2NH$, $C_2H_5NH_2$, $(C_2H_5)_3N$

(a) $(C_2H_5)_2NH > C_2H_5NH_2 > (C_2H_5)_3N$
(b) $C_2H_5NH_2 > (C_2H_5)_2NH > (C_2H_5)_3N$
(c) $(C_2H_5)_3N > (C_2H_5)_2NH > C_2H_5NH_2$
(d) $(C_2H_5)_3N > C_2H_5NH_2 > (C_2H_5)_2NH$

58. Arrange aniline (I), *p*-nitroaniline (II) and *p*-methoxyaniline (III) in order of decreasing basic strength.

(a) III > I > II (b) I > II > III
(c) II > I > III (d) III > II > I

59. Arrange *p*-methylaniline (I), *m*-methylaniline (II), aniline (III) and *o*-methylaniline (IV) in order of decreasing basic strength.

(a) II > I > III > IV (b) IV > III > II > I
(c) I > II > III > IV (d) III > II > I > IV

60. In the reaction

$$CH_3NH_2 \xrightarrow{\text{excess } CH_3Cl} X \xrightarrow[\text{moist}]{Ag_2O} Y \xrightarrow{\Delta} Z$$

the final product Z is

(a) $(CH_3)_3N$ (b) $(CH_3)_4N^+Cl^-$
(c) $(CH_3)_4N^+OH^-$ (d) $(CH_3)_2NH$

61. In the reaction

$$C_6H_5NH_2 + C_6H_5CHO \longrightarrow X \xrightarrow{\text{Raney Ni}} Y$$

the product Y is

(a) $C_6H_5N{=}CHC_6H_5$ (b) $C_6H_5NHCH_2C_6H_5$
(c) $(C_6H_5NH)_2CHC_6H_5$ (d) none of these

62. Aniline produces a Schiff base on reaction with

(a) ammonia (b) acetyl chloride
(c) benzaldehyde (d) acetone

63. In the reaction $C_2H_5NH_2 + HNO_2 \longrightarrow$ the products obtained are

(a) $C_2H_5NO_2$ (b) C_2H_5OH, N_2, H_2O
(c) $C_2H_5N_2^+Cl^-$ (d) C_2H_5NHOH, NH_3

64. The presence of primary amines can be confirmed by reaction with

(a) HNO_2 (b) $CHCl_3$ and alcoholic KOH
(c) Grignard reagent (d) acetyl chloride

65. Dimethylamine reacts with HNO_2 to produce

(a) CH_3OH (b) $N_2 + CH_3OH$
(c) $(CH_3)_2NH^+NO_2^-$ (d) $(CH_3)_2NNO$

66. Benzenediazonium chloride reacts with hypophosphorus acid to produce

(a) benzene (b) a phenol
(c) cyanobenzene (d) chlorobenzene

67. In piperidine, the N atom involves the hybridization

(a) sp (b) sp^2 (c) sp^3 (d) dsp^2

68. In the reaction $C_6H_5NH_2 + CS_2 \xrightarrow[\Delta]{HgCl_2}$ the product obtained is

(a) phenyl cyanide (b) phenyl isocyanide
(c) phenyl isothiocyanate (d) *p*-aminobenzene sulphonic acid

69. In the reaction $CH_3CH_2NH_2 + CH_3MgBr \longrightarrow X$, the product is

(a) CH_3CH_3 (b) $CH_3CH_2CH_3$
(c) $CH_3CH_2CH_2CH_3$ (d) CH_4

70. Diethylamine reacts with HNO_2 to produce

(a) $(C_2H_5)_2\,NH^+NO_2^-$ (b) $(C_2H_5)_2NNO$
(c) $N_2 + C_2H_5OH$ (d) C_2H_5OH

71. The product obtained in the reaction

$$CH_3CH_2CONH_2 \xrightarrow[\text{(ii) KOH}]{\text{(i) bromine water}} X$$

is

(a) CH_3CH_2COOH (b) $CH_3CH_2CH_2NH_2$
(c) $CH_3CH_2NH_2$ (d) $CH_3CH_2COONH_4$

72. Arrange *p*-toluidine (I), *N,N*-dimethyl-*p*-toluidine (II), *p*-nitroaniline (III) and aniline (IV) in order of decreasing basicity.

(a) I > IV > III > II (b) I > II > III > IV
(c) II > I > IV > III (d) III > I > II > IV

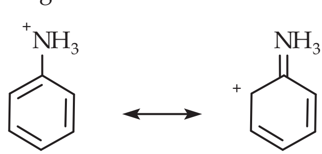
73. Arrange methylamine (I), dimethylamine (II), aniline (III) and *N*-methylaniline (IV) in order of decreasing basicity.

(a) I > II > III > IV (b) II > I > IV > III
(c) III > II > I > IV (d) IV > III > II > I

74. Gabriel phthalimide synthesis is used for the preparation of

(a) primary aromatic amines (b) primary aliphatic amines
(c) secondary amines (d) tertiary amines

75. Consider the following structure for the anilium ion.



I II

Which of the following statements are correct regarding this structure?

(a) It is not an acceptable canonical structure because it is nonaromatic.

(b) It is not an acceptable canonical structure because here nitrogen has ten valence electrons.

(c) It is an acceptable canonical structure.

(d) It is not an acceptable canonical structure because carbonium ions are less stable than ammonium ions.

76. Arrange phenol (I), *p*-cresol (II), *m*-nitrophenol (III) and *p*-nitrophenol (IV) in order of decreasing acidity.

(a) II > I > III > IV (b) IV > III > I > II
(c) III > IV > I > II (d) I > IV > III > II

77. The major product of the reaction between *p*-chlorotoluene and KNH_2 in liquid NH_3 is

(a) *o*-toluidine (b) *m*-toluidine
(c) *p*-toluidine (d) *p*-chloroaniline

78. Which of the following is a Sandmeyer reaction?

(a) $C_6H_5N_2Cl \xrightarrow[\Delta]{\text{cuprous chloride}} C_6H_5Cl + N_2$

(b) $2C_6H_5Cl \xrightarrow{CuCl_2/HCl} C_6H_6 + Cl_2$

(c) $C_6H_5OH \xrightarrow{\text{Zn dust}} C_6H_6 + ZnO$

(d) $C_6H_5NO_2 + 6H \xrightarrow{Sn + HCl} C_6H_5NH_2 + 2H_2O$

79. Which of the following compounds will produce a *p*-nitroso derivative on treatment with $NaNO_2/HCl$ at 0–5°C?

(a) Aniline (b) *N*-methylaniline
(c) *o*-Methylaniline (d) *N,N*-dimethylaniline

80. Which of the following reactions will produce benzenesulphonic acid?

(a) Benzene $\xrightarrow{\text{conc. } H_2SO_4\text{, 80°C}}$

(b) Benzene $\xrightarrow{\text{fuming sulphuric acid, 200–250°C}}$

(c) Benzene $\xrightarrow{\text{chlorosulphonic acid}}$

(d) Benzene $\xrightarrow{\text{sulphuryl chloride, pyridine}}$

81. Nitrobenzene can be converted into azoxybenzene by reduction with

(a) $Na_3AsO_3/NaOH/H_2O$ (b) $Zn/NaOH/CH_3OH$
(c) Sn + HCl (d) $Zn/NH_4Cl/H_2O$

82. Benzenediazonium chloride can be converted into phenol by treating it with

(a) H_3PO_3, H_2O, CuCl (b) H_2O, heat
(c) alcohol, heat (d) HBF_4 and $NaNO_2/Cu$

83. Arrange CH_3NH_2 (I), CH_3CONH_2 (II) and NH_2CH_2COOH (III) in order of decreasing basicity.

(a) I > III > II (b) III > II > I
(c) II > I > III (d) II > III > I

84. The bond angles in methane (I), ammonia (II) and trimethylamine (III) increase in the order

(a) I > III > II (b) I > II > III

(c) II > I > III (d) III > II > I

85. Arrange the following compounds in order of decreasing basic strength.

CH_3NH_2	$(CH_3)_2NH$	$(CH_3)_3N$	NH_3
I	II	III	IV

(a) I > II > III > IV (b) II > I > III > IV

(c) IV > III > II > I (d) II > III > I > IV

86. How many structures are possible for a compound having the molecular formula $C_3H_7NO_2$?

(a) One (b) Two (c) Three (d) Four

• Type 2 •

Choose the correct options. More than one option is correct.

87. Which of the following reaction sequences will give aniline as the final product?

(a) Benzene $\xrightarrow[H_2SO_4]{HNO_3} [\quad] \xrightarrow[2.\ NaOH/H_2O]{1.\ Sn/HCl}$

(b) $C_6H_5\overset{\overset{\displaystyle O}{\|}}{C}Cl \xrightarrow{NH_3} [\quad] \xrightarrow[(Br_2/OH^-)]{OBr^-}$

(c) $C_6H_5CH_2Br \xrightarrow{\text{excess } NH_3} [\quad] \xrightarrow[2.\ H_3PO_2]{1.\ HONO}$

(d) None of these

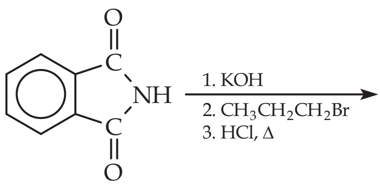
88. Which of the following reagents can be used to distinguish between *p*-$O_2NC_6H_4NH_2$ and C_6H_5COOH?

(a) $KMnO_4$ (b) Br_2/CCl_4 (c) NaOH (d) HCl

89. Which of the following methods can be used to prepare *n*-propylamine?

(a) $CH_3CH_2CH_2Br \xrightarrow[\text{conc. } H_2SO_4]{NaN_3,\ \text{warm}}$

(b) $CH_3CH_2CH_2CONH_2 \xrightarrow{Br_2/KOH}$

(c) 

(d) $CH_3CH_2CH_2Br + NH_4OH \longrightarrow$

90. Which of the following statements are correct regarding thiol esters?

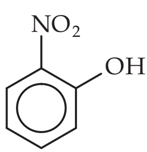
(a) They are not as effectively stabilized as their oxygen analogues.

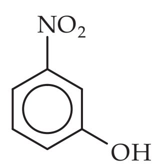
(b) In thiol esters, the α-hydrogens are more acidic than those of ordinary esters.

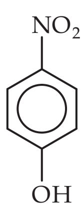
(c) The C—S bond of a thiol ester is weaker than the C—O bond of an ordinary ester.

(d) $R—\bar{S}:$ is a better leaving group that $R—\bar{O}:$.

91. On being heated with solid potassium hydroxide, nitrobenzene gives

(a) 

(b) 

(c) 

(d) There is no reaction.

92. The synthesis of α-benzylethylamine using an appropriately substituted derivative of α-benzylpropionic acid occurs with retention of configuration in

(a) the Schmidt reaction
(b) the Curtius rearrangement
(c) the Lossen rearrangement
(d) none of these

93. Which of the following statements are correct?

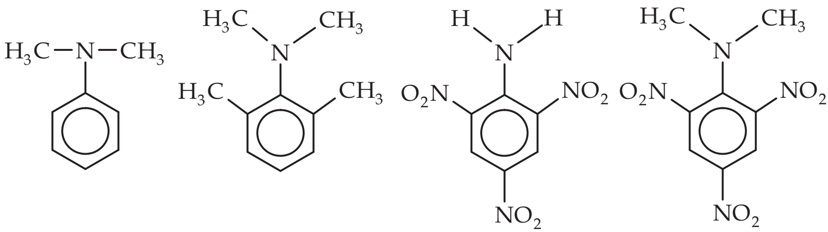
(a) Pyridine is a stronger base than ethylamine.

(b) The basic strength of trimethylamine is less than that of dimethylamine.

(c) Ethyl amine is a stronger base than ammonia.

(d) Aniline is a weaker base than ammonia.

94. Consider the structures



I II III IV

Which of the following statements are correct?

(a) The base strength of II is more than that of I.

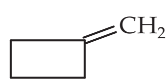
(b) The base strength of II is less than that of I.

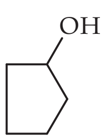
(c) The base strength of IV is more than that of III.

(d) The base strength of IV is less than that of III.

95. Treatment of cyclobutylmethylamine,  with nitrous acid gives

(a) 

(b) 

(c) 

(d) 

96. Treatment of *n*-propylamine with nitrous acid gives

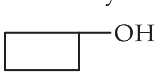
(a) $CH_3CH{=}CH_2$

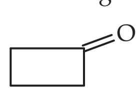
(b) $CH_3—CH_2—CH_2OH$

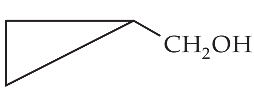
(c) $CH_3—\underset{\displaystyle OH}{\underset{|}{CH}}—CH_3$

(d) none of these

97. The reaction of cyclobutylamine with nitrous acid gives

(a) 

(b) 

(c) 

(d) none of these

98. Which of the following statements are correct for trimethylamine?

(a) It has a trigonal pyramidal shape.

(b) The C–N–C bond angle is 108.7°.

(c) The N atom is sp^3-hybridized.

(d) The unshared pair of electrons on nitrogen occupies an sp^2 orbital.

99. Which of the following compounds are likely to react with an appropriate base to generate a negative charge on the C atom adjacent to the S atom?

(a) $C_6H_5—SCH_3$

(b) $CH_3—\overset{\overset{\Large O}{\|}}{S}—CH_3$

(c) $CH_3—SH$

(d) $C_6H_5—SH$

100. Which of the following statements are correct?

(a) Thiol esters are more susceptible to nucleophilic attack than normal esters.

(b) Thiol esters are less susceptible to nucleophilic attack thn normal esters.

(c) The α-hydrogens of thiol esters are more acidic than those of ordinary esters.

(d) The carbon-sulphur bond of a thiol ester is weaker than the carbon-oxygen bond of an ordinary ester.

101. The intermediates obtained in the reaction

$$R-\overset{\overset{O}{\|}}{C}-Cl \xrightarrow[\text{heat}]{NaN_3} R-NH_2$$

are

(a) $R—\overset{\overset{O}{\|}}{C}—\overset{-}{N}—\overset{+}{N}{\equiv}N$

(b) $R—N{=}C{=}O$

(c) $R—CNO$

(d) none of these

102. Which of the following statements are correct?

(a) Thiols do not form as strong intermolecular hydrogen bonds as do alcohols.

(b) Thiols are considerably stronger acids than the corresponding alcohols.

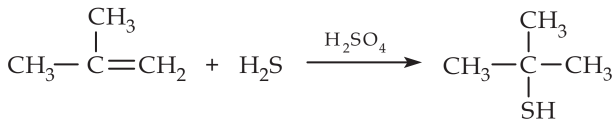
(c) Thiols are much weaker acids than the corresponding alcohols.

(d) Thiols form insoluble salts with heavy metals, e.g., mercury.

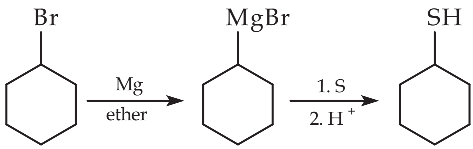
103. Which of the following reactions are feasible for the preparation of thiols?

(a) $C_2H_5Br + NaSH \longrightarrow C_2H_5SH + NaBr$

(b)



(c)

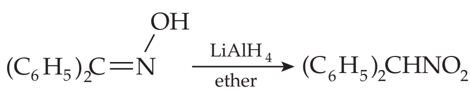


(d) $C_2H_5OH + H_2S \longrightarrow C_2H_5SH$

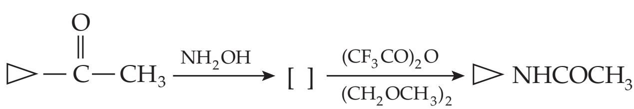
104. Which of the following are feasible?

(a) $CH_3CH_2CH_2CN \xrightarrow[\text{ether}]{LiAlH_4} CH_3CH_2CH_2CH_2NH_2$

(b)



(c)



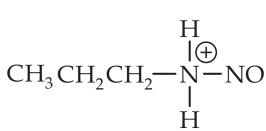
(d) $C_6H_5—CH_2CO_2H + NH_3 \xrightarrow[CHCl_3]{H_2SO_4} C_6H_5CH_2NH_2$

105. In the reaction

$$CH_3CH_2CH_2NH_2 \xrightarrow[0\text{–}5°C]{NaNO_3/\text{dil. HCl}} CH_3CH{=}CH_2$$

the possible intermediates are

(a)



(b) $CH_3CH_2CH_2—N{=}N—OH$

(c) $CH_3CH_2CH_2—\overset{+}{N}{\equiv}N$

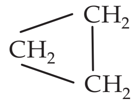
(d) $CH_3CH_2\overset{+}{C}H_2$

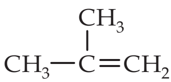
106. In the reaction

$$CH_3CH_2CH_2NH_2 \xrightarrow[0\text{–}5°C]{NaNO_2/\text{dil. HCl}}$$

the products formed are

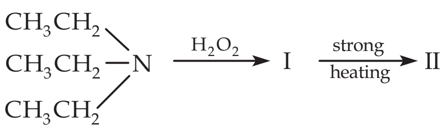
(a) $CH_3CH{=}CH_2$

(b) 

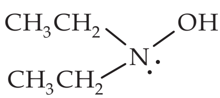
(c) 

(d) none of these

107. The final products (II) obtained in the reaction

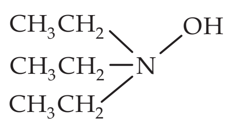


are

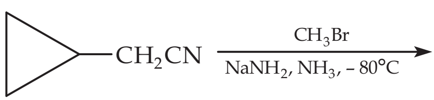
(a) 

(b) $CH_2{=}CH_2$

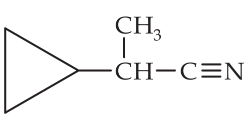
(c) $CH_3CH{=}CH_2$

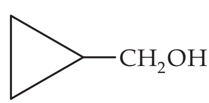
(d) 

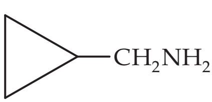
108. In the reaction

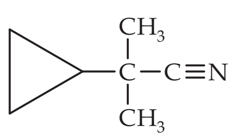


the products obtained are

(a) 

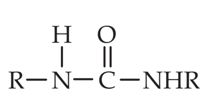
(b) 

(c) 

(d) 

109. The products obtained by the reaction of an isocyanate (R—N=C=O) with water are

(a) RNH_2

(b) 

(c) RNHOH

(d) none of these

110. The reaction of $CH_3(CH_2)_6Br$ with $NaNO_2$ in the presence of dimethylformamide gives

(a) $CH_3(CH_2)_6OH$ (b) $CH_3(CH_2)_6NO_2$

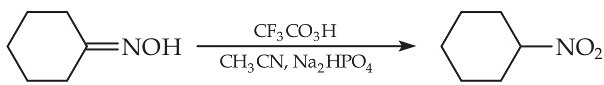
(c) $CH_3(CH_2)_6ONO$ (d) There is no reaction.

111. Which of the following reactions are feasible?

(a) $(CH_3)_3CNH_2 \xrightarrow[\text{acetone + water}]{KMnO_4} (CH_3)_3C{-}NO_2$

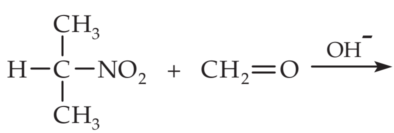
(b) $ICH_2{-}CO_2C_2H_5 + AgNO_2 \xrightarrow[\text{ether}]{0°C} O_2NCH_2CO_2C_2H_5 + AgI$

(c)



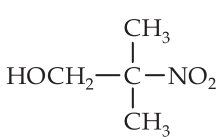
(d)

112. The products obtained in the reaction

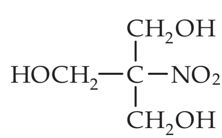


are

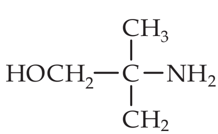
(a)



(b)



(c)



(d) none of these

113. The conversion $CH_3CN \longrightarrow CH_3CH_2NH_2$ can be effected by using

(a) Pt/H_2 (b) $LiAlH_4$

(c) Na/C_2H_5OH (d) $SnCl_2/HCl$

114. Ammonium acetate can be converted into acetamide by

(a) heating

(b) heating in the presence of P_2O_5

(c) using Br_2/KOH

(d) heating in the presence of CH_3COOH

115. Phenyl cyanide can be obtained by

(a) $C_6H_5CONH_2 \xrightarrow{P_2O_5,\ \Delta}$

(b) $C_6H_5{-}CH{=}NOH \xrightarrow{Ac_2O,\ \Delta}$

(c) $C_6H_5Cl \xrightarrow{\text{alc. KOH}}$

(d) $C_6H_5NH_2 \xrightarrow[\text{2. CuCN}]{\text{1. NaNO}_2\text{/HCl}}$

116. Which of the following compounds will undergo carbylamine reactions?

(a) $CH_3CH_2NH_2$ (b) $(CH_3)_2NH$

(c) $C_6H_5NH_2$ (d) $(CH_3)_3N$

117. In the reaction

$$CH_3CONH_2 \xrightarrow{Br_2 + KOH} CH_3NH_2$$

the intermediates involved are

(a) $CH_3CONHBr$ (b) CH_3NHBr

(c) $CH_3N{=}C{=}O$ (d) CH_3CONBr_2

118. In the reaction

$RCONH_2 + X \longrightarrow RNH_2$, the reagent X is

(a) PCl_5 (b) $NaOH + Br_2$

(c) soda lime (d) NaOBr

119. Which of the following would react with nitrobenzene to produce hydrazobenzene?

(a) $Na_3AsO_3 + NaOH$ (b) $Zn/NaOH$, CH_3OH

(c) Zn, NaOH (d) NH_2NH_2 + alc. KOH

120. The conversion of *m*-dinitrobenzene into *m*-nitroaniline can be brought about with

(a) $(NH_4)_2S$ (b) sodium polysulphide

(c) Sn + HCl (d) $Zn + NH_4Cl$

121. Nitrobenzene can be converted into azobenzene by reduction with

(a) $LiAlH_4$/ether (b) Zn, NH_4Cl, Δ

(c) Zn/NaOH, CH_3OH (d) Raney Ni

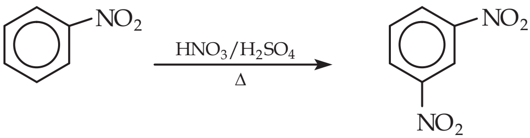
122. The nitration of aromatic organic compounds can be effected by

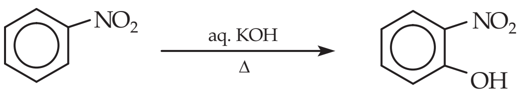
(a) a mixture of concentrated HNO_3 and concentrated H_2SO_4

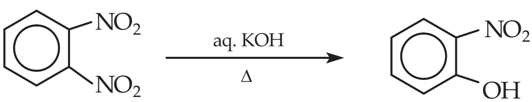
(b) a mixture of concentrated HNO_3 and acetic anhydride

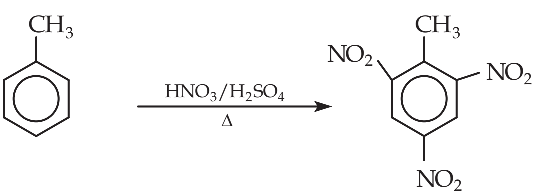
(c) fuming nitric acid and concentrated sulphuric acid
(d) alcoholic potassium nitrate

123. Which of the following represents electrophilic substitution?

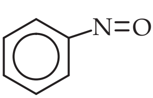
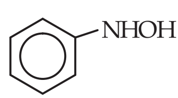
(a) 

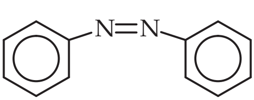
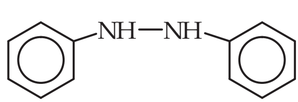
(b) 

(c) 

(d) 

124. In the reduction of nitrobenzene into aniline, the intermediates formed are

(a) 
(b) 

(c) 
(d) 

125. Benzylamine can be prepared by

(a) $C_6H_5CONH_2 \xrightarrow[\text{ether}]{LiAlH_4}$

(b) $C_6H_5CH_2CONH_2 + Br_2 + KOH \longrightarrow$

(c) $C_6H_5CN \xrightarrow{LiAlH_4}$

(d) $C_6H_5CH_2NC \xrightarrow{LiAlH_4}$

126. Isopropylamine can be obtained by

(a) $(CH_3)_2CHO + NH_2OH \longrightarrow\ ?\ \xrightarrow{LiAlH_4}$

(b) $(CH_3)_2CHO + NH_3 \xrightarrow[\Delta]{} ? \xrightarrow{H_2/Ni}$

(c) $(CH_3)_2CHOH + NH_3 \longrightarrow$

(d) none of these

127. Which of the following statements are correct?

(a) In the case of primary, secondary and tertiary amines, the basic strength depends on the extent of hydrogen bonding in the protonated amines.

(b) The presence of groups like —OCH_3 and —CH_3 increases the basic strength of amines.

(c) The presence of groups like —NO_2, —CN and halogens reduces the basic strength of amines.

(d) The basic strength of amines depends on their concentration.

128. Which of the following statements are correct?

(a) Aniline is a weaker base than ethylamine.

(b) Aniline is a stronger base than *p*-methoxyaniline.

(c) Aniline must be acetylated before nitration with an acid mixture.

(d) Aniline is soluble in an ammonium hydroxide solution.

129. An aliphatic nitro compound turns red with the addition of a concentrated NaOH solution, followed by the addition of an excess of an $NaNO_2$ solution and then dilute H_2SO_4. The colour disappears with the addition of the excess of an acid but reappears if the solution is made alkaline. The aliphatic nitro compound is

(a) $CH_3CH_2NO_2$ (b) $(CH_3)_2CHNO_2$

(c) $(CH_3)_3CNO_2$ (d) $CH_3CH_2CH_2NO_2$

130. *p*-Nitroaniline is obtained by

(a) sulphanilic acid $\xrightarrow{HNO_3}$

(b) benzenesulphonic acid $\xrightarrow{HNO_3/H_2SO_4}$

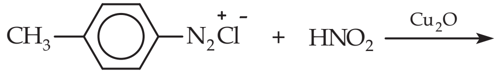
(c) aniline $\xrightarrow[\text{2. aq. NaOH}]{\text{1. } HNO_3/H_2SO_4}$

(d) aniline $\xrightarrow[\text{3. aq. NaOH, }\Delta]{\text{1. acetylation, 2. } HNO_3/H_2SO_4}$

131. *p*-Nitrotoluene can be obtained by

(a) toluene $\xrightarrow{\text{conc. } HNO_3/\text{conc. } H_2SO_4,\ 30^\circ C}$

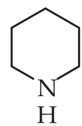
(b) toluene $\xrightarrow{CH_3CO—O—NO_2}$

(c) 

(d) toluene $\xrightarrow{\text{conc. } HNO_3 + \text{conc. } H_2SO_4,\ > 50°C}$

132. Which of the following amines will react with cyclohexanone to give enamine?

(a) CH_3NH_2 (b) $(CH_3)_2NH$

(c)  (d) 

133. Intermolecular hydrogen bonding is possible in the case of

(a) *N*-methylaniline (b) *N,N*-dimethylaniline

(c) methylamine (d) nitrobenzene

134. Which of the following amines can form hydrogen bonds within themselves?

(a) CH_3NH_2 (b) $(CH_3)_2NH$

(c) $(CH_3)_3N$ (d) None of these

135. Which of the following reactions can be used to prepare ethyl isocyanide?

(a) $CH_3CH_2I + AgCN \xrightarrow{C_2H_5OH/H_2O}$

(b) $CH_3CH_2I + KCN \xrightarrow[\Delta]{\text{alcohol}}$

(c) $CH_3CH_2NH_2 + CHCl_3 + KOH \xrightarrow[\Delta]{\text{alcohol}}$

(d) $CH_3CH_2Cl + KCN \xrightarrow[\Delta]{\text{alcohol}}$

136. The conversion

$$C_6H_5NO_2 \longrightarrow C_6H_5\overset{\overset{\displaystyle O}{\uparrow}}{N}{=}N{-}C_6H_5$$

can be brought about by reduction with

(a) Na_3AsO_3/NaOH (b) Glucose/NaOH

(c) Zn/NaOH (d) $LiAlH_4$/ether

137. The electrolytic reduction of nitrobenzene in a strong acidic medium gives

(a) aniline (b) phenylhydroxylamine

(c) *p*-aminophenol (d) phenylhydrazine

138. The product obtained in the reaction

$$CH_3—NO_2 + Cl_2 + NaOH \longrightarrow$$

is

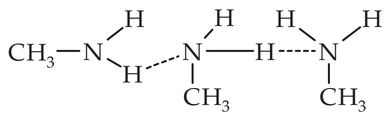
(a) $ClCH_2NO_2$ (b) Cl_2CHNO_2
(c) Cl_3CNO_2 (d) CH_3NH_2

Answers

1. b	**2.** a	**3.** c	**4.** b	**5.** d
6. c	**7.** c	**8.** c	**9.** b	**10.** b
11. d	**12.** b	**13.** c	**14.** a	**15.** b
16. d	**17.** c	**18.** d	**19.** a	**20.** a
21. d	**22.** a	**23.** b	**24.** a	**25.** a
26. a	**27.** d	**28.** a	**29.** d	**30.** b
31. b	**32.** d	**33.** b	**34.** a	**35.** b
36. a	**37.** b	**38.** a	**39.** b	**40.** a
41.b	**42.** a	**43.** b	**44.** b	**45.** c
46. a	**47.** b	**48.** b	**49.** c	**50.** a
51. c	**52.** c	**53.** d	**54.** a	**55.** a
56. a	**57.** a	**58.** a	**59.** a	**60.** a
61. b	**62.** c	**63.** b	**64.** b	**65.** d
66. a	**67.** c	**68.** c	**69.** d	**70.** b
71. c	**72.** c	**73.** b	**74.** b	**75.** b
76. b	**77.** b	**78.** a	**79.** d	**80.** a
81. a	**82.** b	**83.** a	**84.** a	**85.** b
86. d	**87.** a, b	**88.** c, d	**89.** a, b, c	**90.** a, b, c, d
91. a, c	**92.** a, b, c	**93.** b, c, d	**94.** a, c	**95.** a, b, c, d
96. a, b, c	**97.** a, c	**98.** a, b, c	**99.** a, b	**100.** a, c
101. a, b	**102.** a, b, d	**103.** a, b, c	**104.** a, b, c, d	**105.** a, b, c, d
106. a, b	**107.** a, b	**108.** a, d	**109.** a, b	**110.** b, c
111. a, b, c	**112.** a, b	**113.** a, b, c	**114.** b, d	**115.** a, b, d
116. a, c	**117.** a, c	**118.** b, d	**119.** c, d	**120.** a, b
121. a, c	**122.** a, b, c	**123.** a, d	**124.** a, b	**125.** a, b, c
126. a, b, c	**127.** a, b, c	**128.** a, c	**129.** a, d	**130.** a, d
131. a, c	**132.** b, c, d	**133.** a, c	**134.** a, b	**135.** a, c
136. a, b	**137.** b, c	**138.** a, b, c		

Hints to More Difficult Problems

4. Hydrogen bonding is possible only in molecules that have hydrogen atoms bound to electronegative atoms.



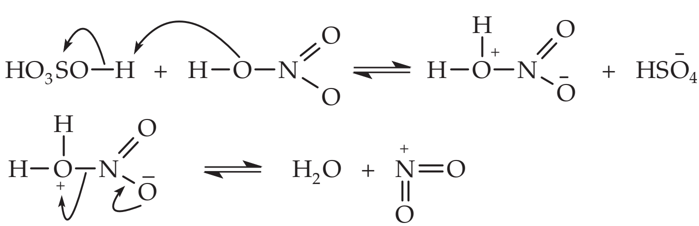
7. Aliphatic amines are generally stronger than aromatic amines.

22. When amides containing a chiral carbon react with $NaOBr/H_2O$, there is retention of configuration at the migrating atom.

23. The strong electron-withdrawing effect of the nitro- group coupled with the formation of the resonance-stabilized cyclohexadienylide anion constitutes the driving force for the nucleophilic attack by the hydroxide anion.

28. Primary and secondary nitro-compounds undergo aldol-type and Michael additions with suitable carbonyl compounds under the influence of basic catalysts.

46. A mixture of concentrated HNO_3 and concentrated H_2SO_4 is termed a nitrating mixture.



Nitronium ion reactive electrophile

51. The disubstituted benzene in which all the four hydrogen atoms are identical will give only one monosubstituted product.

53. Two types of compounds can be represented by the molecular formula C_7H_9N in case of monosubstitution.

$$C_7H_9N - C_6H_5 = —CH_2NH_2$$

One possible compound is $C_6H_5CH_2NH_2$ and the other $C_6H_5NHCH_3$.

In case of disubstitution, the possible compound is

$$C_7H_9N—C_6H_4{=}CH_3NH_2.$$

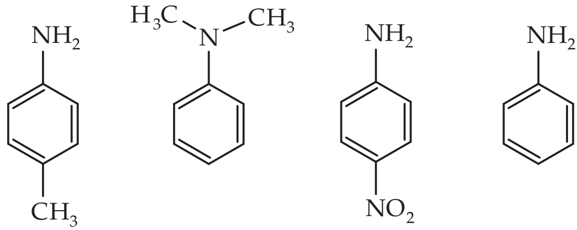
This is aminotoluene, which can be *o*-, *m*- or *p*-.

Therefore, in all, there can be five isomers.

63. On reaction with nitrous acid, primary amines yield alcohols.

66. Benzenediazonium chloride undergoes deamination upon reaction with hypophosphorus acid.

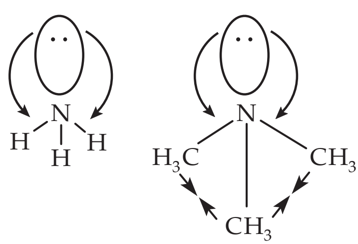
72.



I II III IV

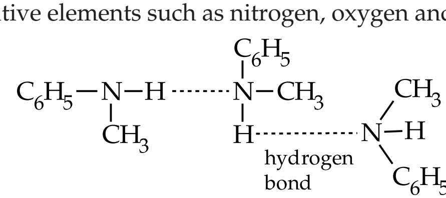
In the reaction of these anilines with H^+, electron release tends to disperse the positive charge of the resultant anilinium salt and thus stabilizes the ions relative to the amine. Electron withdrawal tends to intensify the positive charge and thereby destabilizes the ions with respect to aniline. But N,N-dimethylaniline is a stronger base than aniline. Because of the steric effect of the two methyls, the lone pair on nitrogen cannot take part in resonance with the benzene ring, and is hence more available for protonation. The correct sequence is II > I > IV > III.

84. All the three molecules are sp^3-hybridized. Since all the bonds in CH_4 are equivalent, the bond angle is 109°28′ the normal value. However, in NH_3 and $N(CH_3)_3$, the fourth sp^3-hybridized orbital is present as a lone pair which repels the rest of the bonds as shown below.



But this repulsion is compensated for by the steric repulsion in trimethylamine, and the H—N—H bond angle in NH_3 is less than the H_3C—N—CH_3 bond angle in triethylamine.

133. Hydrogen bonding is possible only in compounds with bonds between electronegative elements such as nitrogen, oxygen and hydrogen.



❑

8

Petroleum

• *Type 1* •

Choose the correct option. Only one option is correct.

1. The quality of diesel oil for use in diesel engines is determined by
   (a) the composition of the oil
   (b) the octane number
   (c) the cetane number
   (d) the amount of additives added

2. During the fractionation of petroleum, the fraction with the composition C_{12}—C_{18} and a boiling range of 300–400°C is known as
   (a) kerosene oil   (b) diesel oil
   (c) lubricating oil   (d) paraffin wax

3. Which of the following has a cetane number of 100?
   (a) Cetane   (b) α-Methylnaphthalene
   (c) Cyclohexane   (d) None of these

4. On testing, a sample of diesel behaves like a 3 : 2 mixture of cetane and α-methylnaphthalene. The cetane number of the diesel oil is
   (a) 60   (b) 40   (c) 20   (d) 100

5. A good diesel oil should have an octane number of
   (a) 30–40   (b) > 45   (c) 10–30   (d) 5–100

6. For improving the quality of gasoline, the presence of aromatic hydrocarbons, which have a high octane number, is necessary. This is achieved by
   (a) isomerization   (b) alkylation
   (c) reforming   (d) distillation under vacuum

7. The tendency of gasoline to knock decreases with change in the nature of the fuel, i.e., it depends upon whether it comprises straight-chain paraffins (I), branched-chain paraffins (II), olefins (III), aromatic hydrocarbons (IV), as follows

(a) I > II > IIII > IV (b) IV > III > II > I
(c) II > I > IV > III (d) III > II > I > IV

8. The octane number of aviation fuel is above

(a) 50 (b) 75
(c) 80 (d) 100

9. *n*-Heptane has been assigned the octane number

(a) 0 (b) 1000
(c) 10 (d) 50

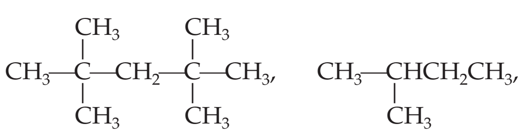
10. The thermal decomposition of higher hydrocarbons into lower hydrocarbons is known as

(a) reforming (b) isomerization
(c) cracking (d) aromatization

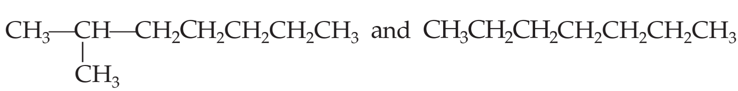
11. Commercial gasoline contains mostly

(a) straight-chain alkanes (b) cycloalkanes
(c) branched-chain alkanes (d) aromatic hydrocarbons

12. Arrange



I II



III IV

in order of their octane numbers.

(a) I > III > II > IV (b) IV > II > III > I
(c) I > II > III > IV (d) II > IV > I > III

13. Liquid hydrocarbons can be converted into a mixture of gaseous hydrocarbons by

(a) hydrolysis
(b) oxidation
(c) cracking
(d) distillation under reduced pressure

14. Petroleum consists mainly of
(a) aromatic hydrocarbons (b) aliphatic hydrocarbons
(c) aliphatic alcohols (d) none of these

15. The first product obtained during the fractional distillation of petroleum is
(a) petroleum ether (b) diesel
(c) kerosene (d) none of these

16. Which of the following fractions of petroleum has the lowest boiling point?
(a) Diesel (b) Kerosene
(c) Gasolene (d) Heavy oil

17. Paraffin wax is
(a) an ester (b) an alcohol
(c) a saturated hydrocarbon (d) an unsaturated hydrocarbon

18. Natural gas is a mixture of
(a) CO and N_2 (b) CH_4, C_2H_6 and C_3H_8
(c) CO and CO_2 (d) CO, H_2 and CH_4

19. Petroleum ether can be used as
(a) a fuel
(b) a solvent for fats, oils and varnish
(c) both
(d) neither

20. Gasoline has the composition
(a) C_3–C_5 (b) C_6–C_{10} (c) C_8–C_{12} (d) C_{10}–C_{13}

21. Synthetic petrol is produced from water gas by the
(a) Baeyer process (b) Fischer–Tropsch process
(c) oxo process (d) Bergius process

22. The detection of leakage from LPG cylinders is facilitated by the addition of
(a) phenols (b) glycols
(c) thioalcohols (d) alcohol

23. Which of the following produce the highest knocking?
(a) Olefins (b) Aromatic hydrocarbons
(c) Straight-chain paraffins (d) Branched-chain paraffins

24. Which of the following has been given the octane number zero?
(a) *n*-Octane (b) Iso-octane
(c) *n*-Heptane (d) Tetraethyl lead

25. Tetraethyl lead is used as a
(a) petroleum additive
(b) mosquito repellent
(c) painkiller
(d) fire extinguisher

26. Which of the following is used as an antiknock compound?
(a) TEL
(b) Lead acetate
(c) Ethyl acetate
(d) All of these

27. Kerosene has the composition
(a) C_5-C_8
(b) C_8-C_{12}
(c) $C_{12}-C_{16}$
(d) $C_{16}-C_{18}$

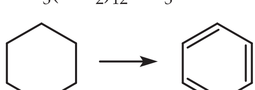
28. A sample of gasoline, on testing, behaves like a mixture of 65% iso-octane and 35% *n*-heptane. What is the octane number of the fuel?
(a) 35
(b) 65
(c) 30
(d) 100

29. Arrange the following in order of their knocking properties. Branched-chain paraffins (I), straight-chain paraffins (II), olefins (III) and napthenes (IV)
(a) I > II > III > IV
(b) I > II > IV > III
(c) II > I > III > IV
(d) I = II > III > IV

• *Type 2* •

Choose the correct options. More than one option is correct.

30. The possible products of the thermal cracking of a straight-chain alkane ($C_{16}H_{34}$) in the presence of a catalyst are
(a) $C_5H_{11}CH{=}CH_2$
(b) $CH_2{=}CHCH_2CH_3$
(c) $CH_3CH_2\overset{\overset{H}{|}}{\underset{\underset{CH_3}{|}}{C}}-CH_3$
(d) none of these

31. Which of the following reactions are possible during cracking?
(a) $CH_3(CH_2)_{12}CH_3 \longrightarrow CH_3(CH_2)_5CH_3 + CH_3(CH_2)_4CH{=}CH_2$
(b)  $+ \ 3H_2$
(c) $CH_3(CH_2)_{12}CH_3 \longrightarrow CH_3(CH_2)_4CH_3$
(d) None of these

32. Which of the following statements are correct?

(a) Iso-octane has a higher octane number than that of *n*-octane.

(b) Cyclohexane has a higher octane number than that of *n*-hexane.

(c) Cyclohexane has a lower octane number than that of *n*-hexane.

(d) Iso-octane has a lower octane number than that of *n*-octane.

33. The thermal cracking of *n*-decane at 450–500°C gives

(a) hexane (b) hexene

(c) pentane (d) pentene

34. Which of the following products are obtained by the refining of petroleum?

(a) Toluene (b) Gasoline

(c) Kerosene oil (d) Carbon tetrachloride

35. Which of the following processes can be used to produce gasoline of a high octane number?

(a) Isomerization (b) Cracking

(c) Alkylation (d) Reforming

36. The presence of oil fields below the surface of the earth can be detected by

(a) a survey of the gravity (b) determining the magnetic field

(c) the seismic method (d) none of these

37. Which of the following statements about natural gas are true?

(a) It is a mixture of gaseous hydrocarbons.

(b) It is used in the manufacture of fertilizers.

(c) It is a mixture of CO and H_2.

(d) It is used as a fuel.

38. The octane number of a fuel can be increased by

(a) isomerization (b) alkylation

(c) reforming (d) fractional distillation

39. Which of the following has an octane number of 100?

(a) 2,2,4-Trimethylpentane (b) 2,2-Dimethylpentane

(c) 2,2,4-Triethylhexane (d) Iso-octane

40. Which of the following are present in coal tar?

(a) Cresols (b) Alkenes

(c) Cycloalkenes (d) Naphtha

41. The carbonization of coal is mostly useful for the production of

(a) coke (b) coal-based organic chemicals

(c) liquor ammonia (d) LPG

42. Which of the following statements are correct?

(a) Straight-chain alkanes have very low octane numbers.

(b) The branching of the chain increases the octane number of a fuel.

(c) Straight- and branched-chain alkanes have octane numbers higher than those of the corresponding cycloalkanes.

(d) Aromatic compounds have high octane numbers.

Answers

1. c	**2.** b	**3.** a	**4.** a	**5.** b
6. c	**7.** a	**8.** d	**9.** a	**10.** c
11. d	**12.** c	**13.** c	**14.** b	**15.** a
16. c	**17.** c	**18.** b	**19.** b	**20.** b
21. b	**22.** c	**23.** c	**24.** c	**25.** a
26. a	**27.** c	**28.** b	**29.** a	**30.** a, b, c
31. a, b, c	**32.** a, b	**33.** a, b, c, d	**34.** b, c	**35.** a, b, c, d
36. a, b, c	**37.** a, b, d	**38.** a, b, c	**39.** a, d	**40.** a, d
41. a, b	**42.** a, b, d			

❑

9

Carbohydrates

• Type 1 •

Choose the correct option. Only one option is correct.

1. Which of the following carbohydrates is a monosaccharide?

(a) Fructose

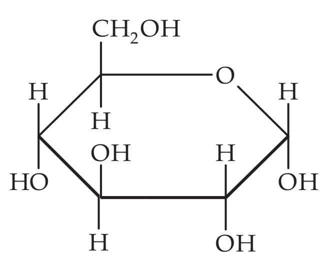
(b) Cellulose

(c) Starch

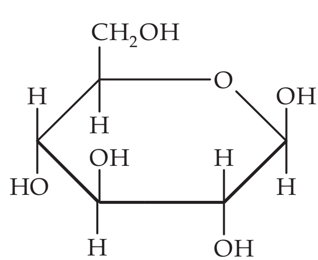
(d) Cane sugar

2. Which of the following structures represents α-D-glucose?

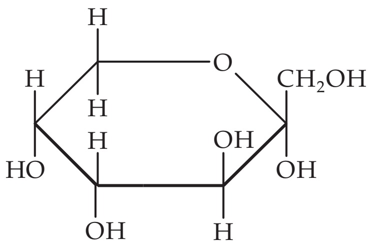
(a)



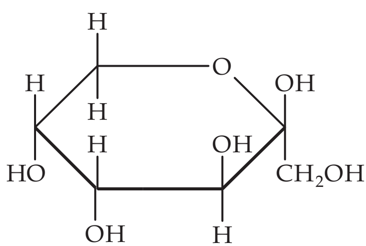
(b)



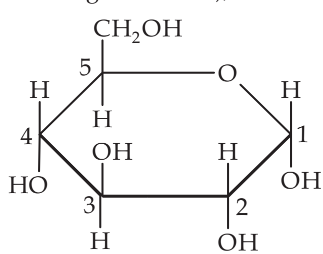
(c)



(d)



3. In α-D-glucose (structure given below), the anomeric carbon is at



(a) 1 (b) 2

(c) 4 (d) 5

4. On hydrolysis, which of the following carbohydrates gives only glucose?

(a) Sucrose (b) Lactose

(c) Maltose (d) Galactose

5. The presence of a primary alcoholic group (CH_2OH) in glucose is inferred by

(a) its oxidation by bromine water to give gluconic acid [$HOOC(CHOH)_4CH_2OH$], which on further oxidation with concentrated HNO_3 yields glucaric acid

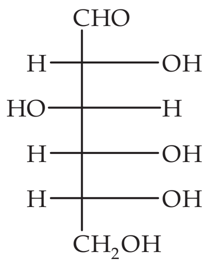
(b) the fact that a solution of glucose in an inert solvent becomes effervescent upon the introduction of sodium

(c) the fact that a solution of it becomes coloured upon the addition of $FeCl_3$

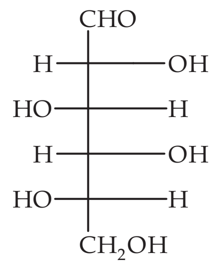
(d) its reaction with the Tollens reagent

6. Which of the following open-chain structures represents D-glucose?

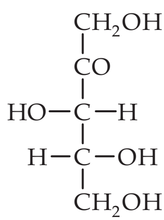
(a)



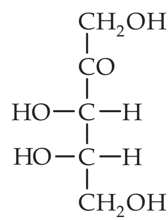
(b)



(c)



(d)



7. In the cyclic structure of glucose, the ring is

(a) only six-membered (b) only five-membered
(c) six- as well as five-membered (d) none of these

8. On hydrolysis followed by heating with HI, the cyanohydrin of which of the following carbohydrates gives 2-methylhexanoic acid?

(a) Glucose (b) Fructose (c) Sucrose (d) Lactose

9. Grape sugar is

(a) glucose (b) fructose (c) maltose (d) lactose

10. Which of the following is fruit sugar?

(a) Glucose (b) Fructose (c) Cane sugar (d) Starch

11. The urine sample of a diabetic patient contains

(a) sucrose (b) fructose (c) glucose (d) all of these

12. Which of the following reduces that Tollens reagent?

(a) Glucose (b) Fructose
(c) Sucrose (d) Starch

13. On oxidation with HNO_3, a carbohydrate ($C_6H_{12}O_6$) gives a mixture of glycolic acid and tartaric acid. The carbohydrate can be

(a) only glucose
(b) only fructose
(c) a mixture of glucose and fructose
(d) none of these

14. An aqueous solution of a carbohydrate turns blue when a drop of iodine solution is added to it. The carbohydrate is

(a) glucose (b) fructose (c) lactose (d) starch

15. On oxidation with HNO_3, a carbohydrate gives a mixture of oxalic acid, tartaric acid and glucaric acid. The carbohydrate is

(a) glucose (b) fructose (c) cane sugar (d) starch

16. Glucose and fructose can be differentiated by using

(a) Fehling's solution (b) the Tollens reagent
(c) Schiff's reagent (d) osazone formation

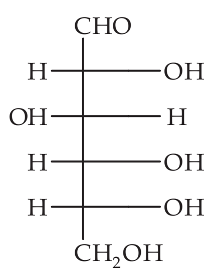
17. On reduction with Na–Hg, a carbohydrate gives a mixture of sorbitol and mannitol. The carbohydrate can be

(a) glucose (b) fructose
(c) cane sugar (d) lactose

18. Which of the following is a disaccharide?

(a) Glucose (b) Maltose
(c) Starch (d) Cellulose

19. A carbohydrate ($C_6H_{12}O_6$) rotates the plane of polarization of polarized light towards the left, and the arrangement of the carbon atoms is as follows.



This carbohydrate is

(a) D(+)-glucose (b) D(–)-glucose
(c) L(+)-glucose (d) L(–)-glucose

• Type 2 •

Choose the correct options. More than one option is correct.

20. Which of the following are disaccharides?

(a) Glucose (b) Cane sugar
(c) Maltose (d) Starch

21. Which of the following statements are correct?

(a) The letters D and L refer to relative configuration around the asymmetric carbon atom.

(b) The signs (+) and (–) refer to the direction of rotation of polarized light.

(c) A carbohydrate with a D configuration must belong to the (+) series.

(d) A carbohydrate with an L configuration must belong to the (–) series.

22. On hydrolysis, which of the following carbohydrates gives only glucose?

(a) Sucrose (b) Lactose

(c) Maltose (d) Starch

23. The presence of a —CHO group in glucose is inferred by its,

(a) reaction with HCN to give a cyanohydrin

(b) reduction by Na–Hg to give sorbitol

(c) reaction with Fehling's solution

(d) reaction with the Tollens reagent

24. Which of the following indicates that all the carbon atoms in glucose are in a straight chain?

(a) On being heated with HI, glucose forms *n*-hexane.

(b) On hydrolysis, the cyanohydrin of glucose gives *n*-heptanoic acid.

(c) On acetylation, glucose gives a penta-acetate.

(d) None of these

25. Which of the following statements are correct for glucose?

(a) It gives a positive reaction to Schiff's test for aldehydes.

(b) It reacts with sodium bisulphite and ammonia.

(c) Glucose penta-acetate does not react with hydroxylamine.

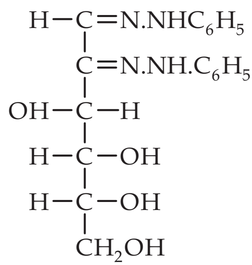
(d) It gives a negative reaction to Schiff's test for aldehydes.

26. The phenomenon of mutarotation is exhibited by

(a) glucose (b) fructose

(c) lactose (d) maltose

27. A carbohydrate gives the following compound on reaction with phenylhydrazine.



The carbohydrate can be

(a) glucose (b) fructose

(c) lactose (d) maltose

28. Which of the following carbohydrates will give the same osazone?

(a) Glucose (b) Fructose

(c) Cane sugar (d) Lactose

29. Which of the following do not undergo hydrolysis?

(a) Glucose (b) Fructose

(c) Cane sugar (d) Maltose

Answers

1. a	**2.** a	**3.** a	**4.** c	**5.** a
6. a	**7.** c	**8.** b	**9.** a	**10.** b
11. c	**12.** a	**13.** b	**14.** d	**15.** c
16. b	**17.** b	**18.** b	**19.** a	**20.** b, c
21. a, b	**22.** c, d	**23.** b, c, d	**24.** a, b	**25.** c, d
26. a, b, c, d	**27.** a, b	**28.** a, b	**29.** a, b	

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10

Amino Acids and Peptides

• *Type 1* •

Choose the correct option. Only one option is correct.

1. Peptide is
   (a) a carbohydrate that gives 3 to 10 monosaccharides on hydrolysis
   (b) the phosphate ester of a nucleoside
   (c) a molecule composed of two or more α-amino acids joined by peptide bonds
   (d) an oxime

2. The proteins are hydrolysed by acids, alkalis or enzymes to give
   (a) amino acids (b) ethers (c) esters (d) cycloparaffins

3. Which of the following amino acids has no asymmetric carbon?
   (a) Histidine (b) Glycine (c) α-alanine (d) Threonine

4. One of the essential α-amino acids is
   (a) lysine (b) glycine (c) serine (d) proline

5. A peptide bond
   (a) is a bond between an oxygen and a carbonyl carbon
   (b) is the amide bond that links the amino acids in a peptide or a protein
   (c) is a bond between a carbonyl carbon and a nitrogen lipid in all kinds of molecules
   (d) none of these

6. The amino acids which has a nonpolar side chain is
   (a) lysine (b) serine
   (c) aspartic acid (d) alanine

7. Amino acids are

(a) acidic
(b) basic
(c) amphoteric
(d) not dipolar ion

8. Which of the folloing statements is correct with reference to glycine?

(a) The acidic functional group is the ammonium $H_3\overset{+}{N}—$ and the basic functional group is the carboxylate ion $—CO_2^-$.
(b) The acidic functional group is the carboxylate ion $—CO_2^-$ and the basic functional group is the ammonium ion $H_3\overset{+}{N}—$
(c) The molecule is chiral.
(d) The molecules are held by intramolecular hydrogen bonds.

9. The total number of essential amino acids is

(a) 10
(b) 20
(c) 24
(d) 18

10. The helical structure of protein is stabilized by

(a) peptide bonds
(b) dipeptide bonds
(c) hydrogen bonds
(d) ionic bonds

11. Which of the following is not found in nucleotides?

(a) Guanine
(b) Cytosine
(c) Adenine
(d) Tryoxine

12. Which parts of amino acids molecules are linked through hydrogen bonds in the secondary structure of proteins?

(a) —COOR group
(b) $—NHCH_3$ group
(C) $—\underset{\underset{O}{\|}}{C}—NH$ group
(d) —OH group

13. Rice is deficient in

(a) alanine
(b) glycine
(c) lysine
(d) leucine

14. Which of the following is not a pyrimidine base?

(a) Thymine
(b) Guanine
(c) Cytosine
(d) Uracil

15. Which of the following structures represent for alanine?

(a) $(CH_3)_2CH-\overset{\overset{+}{N}H_3}{\overset{|}{C}H}\cdot CO_2^-$

(b) $OHCH_2-\overset{\overset{+}{N}H_3}{\overset{|}{C}H}\cdot CO_2^-$

(c) $^-O\overset{\overset{O}{\|}}{C}\cdot CH_2-\overset{\overset{+}{N}H_3}{\overset{|}{C}}HCO_2^-$

(d) $CH_3-\overset{\overset{+}{N}H_3}{\overset{|}{C}H}\cdot CO_2^-$

16. Proteins are detected by

(a) Molisch's test (b) Biuret test

(c) Benedict's test (d) Beilstein test

17. Insulin has 51 amino acids in two polypeptide chains, which are cross-linked by

(a) peroxide bond (b) disulphide bond

(c) diazo bond (d) two carbon-carbon double bond

18. The structures obtained on acidification (H^+) and basification (OH^-) of alanine yields respectively.

(a) $CH_3-\underset{\underset{\overset{+}{N}H_3}{|}}{CH}-COOH$, $CH_3-\underset{\underset{NH_2}{|}}{C}HCOO^-$

(b) $CH_3-\underset{\underset{\overset{+}{N}H_4}{|}}{CH}-COO^-$, $CH_3-\underset{\underset{NH_2OH}{|}}{C}HCOO^-$

(c) $CH_3-\underset{\underset{\overset{+}{N}H_3}{|}}{CH_2}-COO^-$, $CH_3-\underset{\underset{NH}{\|}}{CH}-COO^-$

(d) $CH_3\underset{\underset{\overset{+}{N}H_3}{|}}{CH}-CO\overset{+}{O}H_2$, $HOCH_2-\underset{\underset{\overset{+}{N}H_3}{|}}{C}HCOO^-$

19. The formation of polypeptide bond involves

(a) two α-amino groups and one α-carboxyl group

(b) one α-amino group and two α-carboxyl group

(c) one α-amino group of one molecule and one α-carboxyl group of another molecule

(d) none of these

20. The pK_{a_1} and pK_{a_2} values of alanine (an amino acid) are 2.3 and 9.7 respectively. The isoelectric point (pI) of alanine is

(a) 3.0 (b) 7.0

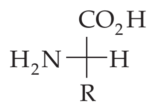
(c) 8.0 (d) 6.0

21. α-amino acid may be prepared by

(a) Williamson synthesis (b) Skraup synthesis

(c) Strecker synthesis (d) Knorr synthesis

22. L-amino acids found in proteins is represented by the formula



In which of the amino acids R contains a basic group

(a) cysteine (b) lysine

(c) aspartic acid (d) valine

• *Type 2* •

Choose the correct options. More than one option is correct.

23. Which of the following statements is correct with reference to amino acids?

(a) A carboxylic acid that contains an amino group

(b) Amino acids are the building blocks of peptides and proteins

(c) An α-amino acid may exists as a zwitterion under suitable condition

(d) none of the above

24. Which of the following statements is correct with reference to isoelectric point?

(a) The isoelectric point is the pH at which the amino acids bear no net charge.

(b) It corresponds to the pH at which the concentration of the zwitterian is at a maximum.

(c) It is not the average of pK_{a_1}, and pK_{a_2} values

(d) All of these

25. Which of the following statements is correct?

(a) No enzyme can convert proteins into amino acids

(b) Uracil may be present in RNA but not in DNA

(c) The left and right ends of the peptides are referred to as the N terminous (or amino terminous) and C terminous (or carboxyl terminous) respectively.

(d) All of these.

Answers

1. c	**2.** a	**3.** b	**4.** a	**5.** b
6. d	**7.** c	**8.** a	**9.** b	**10.** c
11. d	**12.** c	**13.** c	**14.** b	**15.** d
16. b	**17.** b	**18.** a	**19.** c	**20.** d
21. c	**22.** b	**23.** a, b, c	**24.** a, b	**25.** b, c

Hints to More Difficult Problems

2. Amino acids are the basic unit of proteins

6.

$$CH_3-\overset{\overset{+}{N}H_3}{\overset{|}{C}H}\cdot CO_2^-$$

7.

$$H_2N-CH_2-C\begin{matrix}{}^{\nearrow}O\\ {}_{\searrow}OH\end{matrix} \rightleftharpoons H_3\overset{+}{N}\cdot CH_2-C\begin{matrix}{}^{\nearrow}O\\ {}_{\searrow}O^-\end{matrix}$$

It is a neutral molecule and not an ion.

11. The three pyrimidine bases (cytosine, thymine and uracil) and two purine bases (adenine, guanine) are units in nucleotides.

12. Proteins have $-\underset{\underset{O}{\|}}{C}-NH_2$ linkage.

14. Guanine is a purine.

18. Zwitterion is the hybrid of positive and negative ionic groups.

19.

$$\overset{+}{H_3}N-\overset{\overset{R_1}{|}}{CH}-COO^- + \overset{+}{H_3}N-\overset{\overset{R_2}{|}}{CH}-COO^-$$

$$\longrightarrow H_2O + \overset{+}{H_3}N-\overset{\overset{R_1}{|}}{CH}-\overset{\overset{O}{\|}}{C}-NH-\overset{\overset{R_2}{|}}{CH}-COO^-$$

20. $pI = \dfrac{pK_{a_1} + pK_{a_2}}{2} = \dfrac{2.3 + 9.7}{2} = 6.0$

21.

$$\mathrm{RCHO} + \mathrm{NH_3} + \mathrm{HCN} \longrightarrow \underset{\alpha\text{-amino nitrile}}{\underset{\displaystyle\mathrm{NH_2}}{\underset{|}{\mathrm{RCHCN}}}} \xrightarrow{\mathrm{H_3\overset{+}{O}},\ \text{heat}} \underset{\alpha\text{-amino acid}}{\underset{\displaystyle\mathrm{\overset{}{NH_3^+}}}{\underset{|}{\mathrm{R\cdot CHCO_2^-}}}}$$

22. $-CH_2CH_2CH_2CH_2NH_2$

❑

11

Organic Polymers

• *Type 1* •

Choose the correct option. Only one option is correct.

1. Polymer consists of large molecules
   (a) called macromolecules which are made by linking together repeated units of small molecules, called monomer
   (b) called capolymer
   (c) called ε-caprolactum
   (d) all of the above

2. On the basis of intermolecular forces, polymers are classified as
   (a) rubbers
   (b) fibres
   (c) elastomers, fibres, thermoplastics and thermosetting
   (d) amino acids

3. Which of the following is not a natural polymer?
   (a) Wool (b) Silk (c) Cotton (d) Teflon

4. Isoprene on polymerization, produces
   (a) synthetic rubber
   (b) gutta-percha
   (c) neoprene
   (d) *cis*-poly (2-methyl-1,3–butadiene)

5. Natural rubber is obtained from latex, which is a
   (a) mixture of wood, plants and gums
   (b) colloidal dispersion of rubber in water
   (c) mixture of chloroprene and carbohydrate
   (d) none of these

6. Natural silk is
- (a) polyester
- (b) polyamide
- (c) epoxide
- (d) polyurethane

7. Natural rubber is a polymer, derived from
- (a) 1,3-butadiene
- (b) isoprene
- (c) protein
- (d) DNA

8. Step-growth polymers are formed by
- (a) the reaction of a single monomer that possesses two different functional groups A and B.
- (b) the reaction of two different bifunctional monomers and concentrated HNO_3
- (c) the intermolecular reaction of bifunctional molecules
- (d) all of these

9. A polyurethane is the product of
- (a) toluene-2,6-diisocyanate and ethylene glycol in presence of a blowing agent
- (b) $\in$-caprolactum and ethylene glycol
- (c) terephthalic acid and ethylene glycol
- (d) an isocyanate and an alcohol

10. Which of the following is not a copolymer?
- (a) cross copolymer
- (b) block copolymer
- (c) random copolymer
- (d) Graft copolymer

11. Polymeric molecules are held by
- (a) interatomic forces
- (b) coulombic forces
- (c) intermoleculer forces
- (d) gravitational forces

12. The polymers such as polyethylene are
- (a) held together by vander Waals forces
- (b) held together with the forces which operate at long distances
- (c) closely packed with coulombic forces
- (d) none of these

13. Example of thermosetting plastic is/are
- (a) Bakelite
- (b) PVC
- (c) polyurethane
- (d) Mylar

14. Terylene is a condensation polymer of ethylene glycol and
- (a) benzoic acid
- (b) acetic acid
- (c) terephthalic acid
- (d) salicylic acid

15. The fibre obtained by the condensation of hexamethylene diamine and adipic acid is

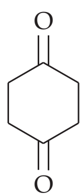
(a) Dacron (b) nylon 6,6
(c) Rayon (d) Teflon

16. A raw material used in making nylon is

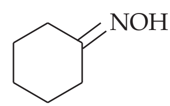
(a) adipic acid (b) 1,3-butadiene
(c) ethyne (d) cyclohexanone

17. ∈-caprolactum is the starting material for the manufacture of nylon 6 and is obtained by Beckmann rearrangement of

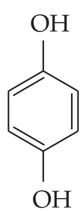
(a)



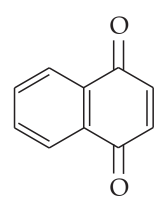
(b)



(c)



(d)



18. The repeating units of PCTFE is

(a) $CF_2{=}CF_2$ (b) $CH_2{=}CH_2$
(c) $CF_3{-}CF_3$ (d) $FClC{=}CF_2$

19. The repeating units of PTFE are

(a) $CH{\equiv}CH$ (b) $CF_3{-}CF_3$
(c) $CH_2{=}CHCN$ (d) $CF_2{=}CF_2$

20. Glyptal is the polymer of ethylene glycol and

(a) terephthalic acid (b) adipic acid
(c) benzoic acid (d) picric acid

21. A polymer which is used for making ropes and carpet fibres is

(a) polyacetylene (b) polypropylene
(c) polyacrylonitrile (d) PVC

22. Hard plastic covers of telephone are made of polymer of

(a) methyl methacrylate (b) venyl acetate
(c) neoprene (d) phenol and formaldehyde

23. The polymer which contains nitrogen is

(a) PVC (b) Teflon

(c) butyl rubber (d) nylon

24. The product of addition polymerization reaction is

(a) PVC (b) nylon

(c) terylene (d) polyamide

25. Cellulose is a condensation polymer of

(a) maltose (b) β-glucose

(c) α-glucose (d) β-fructose

26. Which of the following is a "polyamide"?

(a) Rayon (b) Terylene

(c) nylon (d) Orlon

27. Teflon, polystyrene and neoprene are all

(a) copolymers (b) condensation polymer

(c) homopolymers (d) monomers

28. Teflon

(a) $(-CF_2-CF_2-)_n$ (b) $-(CCl_2-CCl_2)_n$

(c) $-(CBr_2-CBr_2)_n$ (d) CF_2Cl_2

29. The product of addition polymerization reaction is

(a) PVC (b) nylon

(c) Terylene (d) polyamide

30. Isoprene is used in making

(a) petrol (b) nylon

(c) rubber (d) liquid fuel

31. Which of the following is an inert polymer used in coating, particularly in nonstick cookware?

(a) Teflon (b) Cellulose

(c) Bakelite (d) Orlon

32. Cellulose trinitrate, also called "gun cotton" is used in

(a) Cellophane paper (b) dyes

(c) explosives (d) making rayon

33. Cellulose contains glucose units joined by β-1,4-glycosidic linkages. These molecules are held by

(a) ionic bond (b) intramolecular hydrogen bonds

(c) weak vander Waals forces (d) all of these

34. Which of the following cannot serve as a food source for human?
(a) Proteins (b) Starch (c) Enzymes (d) Cellulose

35. Natural rubber is a *cis*-1,4-polyisoprene. During vulcanization, natural rubber is heated with sulphur. As a result, a reaction takes place
(a) that produces cross-links between the *cis*-polyisoprene chains
(b) and makes the rubber much harder
(c) and sulphur reacts both at the double bonds and at allylic hydrogen atoms
(d) all of these

36. Nylon-6,6 is so named because it is a polyamide, formed from a
(a) six-carbon dibase and a six-carbon diamine
(b) six-carbon diacid and a six-carbon diamine
(c) six-carbon diacid and a six-carbon diamide
(d) six-carbon $\in$-caprolactum and a six-carbon diamine

37. Rubber is a
(a) conducting polymer
(b) oriented polymer
(c) elastomer
(d) strong commercially available fabric

• *Type 2* •

Choose the correct options. More than one option is correct.

38. Indicate the correct statement for chain-growth polymers.
(a) Chain-growth polymers are made by the addition of monomers to the end of a growing chain.
(b) The end of a chain is reactive because it is a radical, a cation or an anion.
(c) Polystyrene is the example of this class.
(d) None of the above.

39. Chain-growth polymerization may proceed by the following mechanism
(a) condensation polymerization (b) cationic polymerization
(c) anionic polymerization (d) all of these

40. Examples of chain-growth polymer is/are
(a) polystyrene (b) nylon 6
(c) Teflon (d) all of these

41. Examples of step-growth polymer is/are

(a) nylon 6
(b) nylon 6,6
(c) Kevlar
(d) none of these

42. Polycarbonate is

(a) used in the manufacture of compact disc (CD)
(b) prepared by the reaction between phosgene and bisphenol A
(c) PVC
(d) all of these

43. Epoxy resin is

(a) prepared by the reaction of bisphenol A and epichlorohydrin followed by a hardener
(b) a cross-linked polymer
(c) an epoxy adhesive
(d) all of these

44. Polyacetylene is a conducting polymer and

(a) is prepared by the polymerization of acetylene using a Ziegler-Natta catalyst
(b) the conjugated double bonds in polyacetylene causes it to conduct electricity
(c) is used for the manufacture of electrodes for measuring pH
(d) is not a synthetic metal

45. Crystalline polymers are

(a) denser
(b) harder
(c) heavier and good conductor of heat
(d) all of these

46. Thermoplastic polymers are those

(a) that have ordered crystalline regions and amorphous noncrystalline regions both.
(b) that are hard at room temperature but on heating they become soft enough to be moulded.
(c) that are used in combs, toys, light switch plates and telephone casting.
(d) none of these

47. Thermosetting polymers are

(a) cross-linked chain polymers
(b) hard enough and cannot be remelted by heating

(c) cross-linking reduces the mobility of polymer chains and thus rendered them brittle

(d) all of these

48. Which of the following belong to the class of natural polymers?

(a) Proteins (b) Cellulose

(c) Teflon (d) All of these

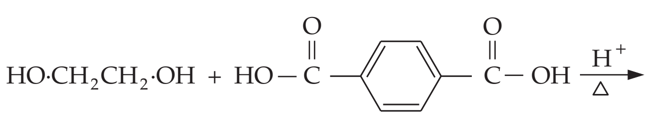
Answers

1. a	**2.** c	**3.** d	**4.** d	**5.** b
6. b	**7.** b	**8.** a	**9.** a	**10.** a
11. c	**12.** a	**13.** a	**14.** c	**15.** b
16. a	**17.** b	**18.** d	**19.** d	**20.** a
21. b	**22.** d	**23.** d	**24.** a	**25.** b
26. c	**27.** c	**28.** a	**29.** a	**30.** c
31. a	**32.** c	**33.** b	**34.** d	**35.** d
36. b	**37.** c	**38.** a, b, c	**39.** b, c	**40.** a, c
41. a, b, c	**42.** a, b	**43.** a, b, c, d	**44.** a, b, c	**45.** a, b
46. a, b, c	**47.** a, b, c, d	**48.** a, b		

Hints to More Difficult Problems

3. Teflon is artificially made as $(\ldots CF_2—CF_2\ldots)_n$

14.



Poly (ethylene terephthalate) + H_2O
Terylene

24. $CH_2{=}CHCl$

30. Isoprene is $CH_2{=}\overset{\overset{\large CH_3}{|}}{C}—CH{=}CH_2$

37. A polymer, that can stretch and then revert back to its original shape is called elastomer.

❑

12

Practical Organic Chemistry

• Type 1 •

Choose the correct option. Only one option is correct.

1. Sulphur present in an organic compound is detected by treating the 'sodium extract' with

(a) potassium ferricyanide (b) potassium ferrocyanide
(c) sodium nitroprusside (d) ammonium thiocyanate

2. Which of the following nitrogenous compounds does not give blue colour in the usual Lassaigne's test for the detection of nitrogen?

(a) Glycine (b) Urea (c) Aniline (d) Hydrazine

3. For the detection of sulphur in an organic compound, sodium nitroprusside is added to the sodium extract of the compound. If sulphur is present, an intense pink to purple colour is obtained due to the formation of

(a) $Fe(CN)_2$ (b) $K_3[Fe(CN)_5NS]$
(c) $Na_4[Fe(CN)_5NO \cdot S]$ (d) $Na_4[Fe(CN)_6]$

4. Lassaigne's test is performed to detect the presence of the elements N, S, X & P in an organic compound. In this test the organic substance is at first fused with

(a) NaCl (b) metallic sodium
(c) metallic copper (d) NaOH

5. In Lassaigne's test, the sulphur present in the organic compound, on fusion with sodium, is converted into

(a) Na_2S (b) C_4H_4S
(c) $Na_2S_2O_3$ (d) CH_3SH

6. Halogens present in organic compounds may be detected by heating the compound on a copper foil in a bunsen nonluminous flame whereby it imparts green colour to the flame. This test is known as

(a) Marsh's test (b) Lassaigne's test
(c) Gutzeit test (d) Beilstein test

7. The sodium extract prepared from sulphanilic acid, contains SCN^-. It gives blood-red colouration with

(a) $FeCl_3$ (b) Na_2CS_3
(c) $FeSO_4$ (d) a mixture of Na_2S and CS_2

8. An organic compound contains C, H, N, S and Cl. For detection of chlorine in the compound, the sodium extract of the compound is at first heated with a few drops of concentrated HNO_3 and then silver nitrate solution is added to get a precipitate of AgCl. This digestion with HNO_3, prior to addition of $AgNO_3$, is required

(a) to prevent the formation NO_2
(b) to convert the CN^- and S^{2-} ions to volatile HCN and H_2S, otherwise, they will interfere with the test by forming AgCN and Ag_2S.
(c) to prevent the hydrolysis of NaCN and Na_2S
(d) to form S_4N_4 which prevent the formation of AgCl with $AgNO_3$

9. In Lassaigne's test, when 'sodium extract' of an organic compound containing both N and S is heated with sodium nitroprusside solution, a blood-red colouration is developed. This is due to the formation of

(a) sodium nitroprusside (b) sodium thiosulphate
(c) ferric sulphocyanide (d) thiourea

10. When a nitrogenous organic compound is fused with sodium, the nitrogen present in the compound is converted into

(a) sodium nitrate (b) sodium nitrite
(c) sodamide (d) sodium cyanide

11. To detect iodine in presence of bromine, the sodium fusion filtrate is treated with $NaNO_2$ + glacial acetic acid + CCl_4. Iodine is detected by the appearance of

(a) purple colour in the organic layer of CCl_4
(b) brown colour in the organic layer of CCl_4
(c) deep blue colour in CCl_4 layer
(d) yellow colour in CCl_4 layer

12. A mixture of acetone and carbon tetrachloride can be separated by

(a) fractional crystallization (b) fractional distillation
(c) steam distillation (d) vacuum distillation

13. Benzoic acid can be separated from a mixture of phenol and benzoic acid by treatment with

(a) $NaHCO_3$ solution (b) NaOH solution
(c) $Na_2S_2O_3$ solution (d) $FeCl_3$ solution

14. Orthonitrophenol can be separated from paranitrophenol by

(a) chromatography (b) solvent extraction
(c) steam distillation (d) sublimation

15. Anthracene can be purified by

(a) sublimation (b) crystallization
(c) distillation (d) filtration

16. Rectified spirit contains

(a) 95.6% ethanol and 4.4% methanol
(b) 100% ethanol
(c) 95.6% ethanol and 4.4% water
(d) 95.6% ethanol and 4.4% benzene

17. A liquid organic compound decomposes at its boiling point. It can be purified by

(a) simple distillation
(b) sublimation
(c) distillation under reduced pressure
(d) all of these

18. Aniline can be separated from phenol using

(a) $NaHCO_3$ (b) dilute HCl
(c) NaCl (d) conc. HNO_3

19. KOH can be used as drying agent for

(a) amines (b) acids
(c) phenols (d) esters

20. Which of the following compounds are purified by steam distillation?

(a) Nitrobenzene (b) Chlorobenzene
(c) Orthonitrophenol (d) All of these

21. Quick time can only be used for drying

(a) ethanol (b) phenols
(c) esters (d) carboxylic acid

22. Silver salt method is used for the determination of molecular weight of

(a) organic bases (b) organic acids
(c) aliphatic amines (d) esters

23. The molecular weight of aniline is determined by

(a) converting it into its chloroplatinate salt and then estimating platinum obtained by ignition of the salt.

(b) converting it into its acetate

(c) making aniline into its tribromo derivative

(d) all of these

24. Which of the following methods is used for the estimation of nitrogen in organic compounds?

(a) Hypobromite method (b) Rast method

(c) Dumas' method (d) Carius method

25. Which of the following methods is used for the estimation of sulphur in organic compounds?

(a) Carius method (b) Victor Meyer's method

(c) Kjeldahl method (d) Dumas' method

26. An organic compound has carbon and hydrogen percentages in the ratio 6 : 1 and carbon and oxygen percentages in the ratio 3 : 4. The compound has the empirical formula

(a) CH_2O (b) CH_4O

(c) C_2H_6O (d) CHO_2

27. 0.0833 mole of a carbohydrate of empirical formula CH_2O contains 1.00 g of hydrogen. The molecular formula of the carbohydrate is

(a) $C_5H_{10}O_5$ (b) $C_3H_4O_3$

(c) $C_{12}H_{22}O_{11}$ (d) $C_6H_{12}O_6$

28. Which of the following aliphatic aldehydes on heating with concentrated NaOH solution gives an yellow resinous precipitate?

(a) CH_3CHO (b) $CCl_3 \cdot CHO \cdot H_2O/CCl_3CH(OH)_2$

(c) HCHO (d) All of these

29. Which of the following compounds will give chloroform on warming with NaOH solution?

(a) $CCl_3CH(OH)_2$ (b) $H \cdot CHO$

(c) CH_3CONH_2 (d) $C_6H_5NHCOCH_3$

30. Which of the following organic compounds will not yield CO_2 when treated with Na_2CO_3 solution?

(a) Benzoic acid (b) Phenol

(c) Sulphanilic acid (d) Orthonitrophenol

31. Phenol and carboxylic acid can be distinguished from each other using

(a) NaOH solution (b) NaCl solution

(c) $NaHCO_3$ solution (d) none of these

32. HCHO and CH_3CHO can be distinguished from each other by the use of
(a) Fehling's solution
(b) ammoniacal silver nitrate solution
(c) evaporation by heating
(d) alkaline $KMnO_4$ solution

33. Acetaldehyde on treatment with alkaline solution of sodium nitroprusside will produce
(a) black colouration
(b) yellow colouration
(c) blue colouration
(d) red colouration

34. Acetaldehyde and acetone can be distinguished by
(a) iodoform test
(b) nitroprusside test
(c) Fehling's solution test
(d) $NaHSO_3$ test

35. Which of the following compounds will not give iodoform test?
(a) CH_3COCH_3
(b) $CH_3CO \cdot C_6H_5$
(c) $CH_3CH_2COCH_2CH_3$
(d) CH_3CH_2OH

36. Methanol and ethanol can be distinguished by
(a) iodoform reaction
(b) esterification
(c) oxidation with acidified $K_2Cr_2O_7$ solution
(d) acrolein test

37. Which of the following observations is correct and is useful in identifying carboxylic acids?
(a) Carboxylic acids liberate CO_2 gas from $NaHCO_3$ solution.
(b) They produce fruity smell of esters when heated with alcohol in presence of concentrated H_2SO_4.
(c) Acids liberate I_2 from a mixture of KIO_3 and KI.
(d) All of these

38. Which of the following carboxylic acids will give "silver-mirror test"?
(a) CH_3CO_2H
(b) $H \cdot CO_2H$
(c) $(COOH)_2$
(d) $CH_3CO \cdot CO_2H$

39. Which of the following compounds will give orange-yellow precipitate with 2,4-dinitrophenylhydrazine reagent?
(a) $CH_3CH_2 \cdot CO_2H$
(b) $CH_3COOC_2H_5$
(c) CH_3COCH_3
(d) C_6H_5OH

40. Which of the following organic compounds will give foul odour of isocyanide on heating with chloroform and alcoholic KOH?

(a) para-toluidine (b) Glycine
(c) Anthranilic acid (d) Sulphanilic acid

41. An organic compound is treated with $NaNO_2$ and dilute HCl at 0°C and then the resulting solution is added to an alkaline solution of β-naphthol whereby a brilliant red dye is produced. This observation indicates that the compound possesses

(a) —NO_2 group (b) —$CONH_2$ group
(c) aromatic —NH_2 group (d) aliphatic —NH_2 group

42. Which of the following aromatic amines will undergo Liebermann's reaction?

(a) $C_6H_5NHCH_3$ (b) $C_6H_5N(CH_3)_2$
(c) $(C_2H_5)_3N$ (d) C_5H_5N

43. Nitrobenzene on heating with a mixture of conc. HNO_3 and conc. H_2SO_4 at 100°C produces

(a) *p*-dinitrobenzene (b) *m*-dinitrobenzene
(c) *o*-diritrobenzene (d) benzene sulphonic acid

• *Type 2* •

Choose the correct options. More than one option is correct.

44. In Lassaigne's test, the organic compound is at first fused with sodium metal. The sodium metal is used because

(a) the melting point of sodium is low so it is easily fused with organic substances
(b) sodium is very much effective to bring about destructive reductions of organic compounds forming ionic inorganic salts NaCN, Na_2S and NaX
(c) all sodium salts are soluble in water.
(d) none of these

45. Which of the following reactions occur during the detection of nitrogen in organic substances by Lassaigne's test?

(a) $Na + C + N \rightarrow NaCN$
(b) $FeSO_4 + 6NaCN \rightarrow Na_4[Fe(CN)_6] + Na_2SO_4$
(c) $3Na_4[Fe(CN)_6] + 2Fe_2(SO_4)_3 \rightarrow Fe_4[Fe(CN)_6]_3 + 6Na_2SO_4$
(d) All of these

46. Which of the following statements is correct?

(a) Two solid organic substances are said to be different if their mixed melting point is depressed below the melting points of both of these.

(b) Ethanol and water cannot be separated from each other completely by simple distillation as they form azeotropic mixture.

(c) Impure glycerine can be purified by ordinary distillation.

(d) All of these.

47. Which of the following observations is correct in context to acetaldehyde?

(a) It usually restores pink colour rapidly to Schiff's reagent.

(b) It does not give silver-mirror test with ammoniacal silver nitrate solution.

(c) It usually reduces Fehling's solution

(d) All of these

48. Which of the following compounds will respond to iodoform test?

(a) $CH_3CHOHCO_2H$ (b) $CH_3CHOHCH_3$

(c) CH_3COCO_2H (d) None of these

Answers

1. c	**2.** d	**3.** c	**4.** b	**5.** a
6. d	**7.** a	**8.** b	**9.** c	**10.** d
11. a	**12.** b	**13.** a	**14.** c	**15.** a
16. c	**17.** c	**18.** b	**19.** a	**20.** d
21. a	**22.** b	**23.** a	**24.** c	**25.** a
26. a	**27.** d	**28.** a	**29.** a	**30.** b
31. c	**32.** c	**33.** d	**34.** c	**35.** c
36. a	**37.** d	**38.** b	**39.** c	**40.** a
41. c	**42.** a	**43.** b	**44.** a, b, c	**45.** a, b, c
46. a, b	**47.** a, c	**48.** a, b, c		

Hints to More Difficult Problems

2. It does not produce NaCN, because N_2H_4 does not contain carbon

7. Sulphanilic acid contains N, S and C which give NaSCN. With $FeCl_3$ it gives blood-red precipitate of $Fe(SCN)_3$

11. $2NaI + 2NaNO_2 + 4HAc \rightarrow I_2 + 2NO + 4NaAc + 2H_2O$

18. Aniline forms $C_6H_5NH_3^+Cl^-$ (solid salt)

19. Amines and KOH are both bases

21. Rest will react with $Ca(OH)_2$ produced by the absorption of water by CaO.

26. $\therefore$ $C : H : O = 6 : 1 : 8,\ \% C : H : O$

$$= 6/15 \times 100 : 1/15 \times 100 : 8/15 \times 100$$
$$= 40 : 6.67 : 53.3$$
$$= 40/12 : 6.67/1 : 53.3/16$$
$$= 3.33 : 6.67 : 3.33$$
$$= 1 : 2 : 1 \text{ i.e. } CH_2O$$

30. Phenol is least acidic among all.

35. Does not have $CH_3CO—C$ group and $CH_3CH(OH)$ group.

40. No odour is detected due to the non-volatility of the acidic isocyanide in the alkaline solution.

42. Secondary amine undergo Liebermann's reaction.

❑

13

Assertions and Reasons

The following questions consist of an *assertion* in column 1 and a *reason* in column 2. Use the following key to choose the appropriate answer.

(a) If the *assertion* as well as the *reason* are correct, and the *reason* is the correct explanation of the *assertion*.

(b) If the *assertion* as well as the *reason* are correct, but the *reason* is not the correct explanation of the *assertion*.

(c) If the *assertion* is correct, but the *reason* is incorrect.

(d) If the *assertion* is incorrect, but the *reason* is correct.

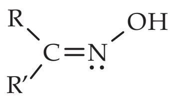
	Assertion	*Reason*
1.	The addition of HCl to alkenes in the presence of peroxides leads to the formation of an anti-Markovnikov product.	The H—Cl bond being stronger, the homolytic cleavage does not favour the production of chlorine free radicals.
2.	The addition of HI to alkenes in the presence of peroxides gives an anti-Markovnikov product.	The homolytic cleavage of HI does lead to the formation iodine free radicals but they combine to form iodine molecules.
3.	In α, β-unsaturated compounds in which C=C and C=O groups are conjugated, there is nucleophilic addition to the C=C bond.	The C=O is stronger than the C=C bond.
4.	In $C_6H_5CH{=}CH{-}CHO$, the addition of C_6H_5MgBr takes place at the C=O bond.	The C=O bond is stronger than the C=C bond.
5.	Acetic acid is stronger than formic acid.	In acetic acid, the electron-releasing inductive effect of the methyl group makes it difficult to break the O–H bond.

6. $NH_3 < MeNH_2 < Me_2NH > Me_3N$ is the order of basicity of the amines shown.	The basicity of amines depends on the magnitude of the +1 effect.
7. In butadiene, the C_2—C_3 single bond is slightly shorter than a carbon-carbon single bond.	The resonating structures of butadiene show that the C_2—C_3 bond has a partial double-bond character.
8. In CH_2=CHBr, the halogen is more reactive than in CH_3CH_2Br.	Due to the +M effect of the halogen, the C—Br bond in vinyl bromide has a partial double-bond character.
9. $\begin{array}{l} CH_3\text{—}\underset{\displaystyle CH_3}{\underset{\vert}{C}H}\text{—}CH{=}CH\text{—}\underset{\displaystyle H}{\underset{\vert}{C}}{=}O \end{array}$ is the major product of the dehydration of 3-hydroxy-4-methylpentanal.	The conjugation of the double bond with the carbonyl group lends resonance stability.
10. The addition of HBr to propene gives 1-bromopropane.	2° carbocations are more stable than 1° carbocations.
11. In the hydrolysis of tertiary butyl chloride by the S_N1 mechanism, the rate-determining step is the ionization of tertiary butyl chloride, leading to the formation of a carbocation.	Since an S_N1 reaction is of the first order, its rate is independent of the concentration of OH^-.
12. The nitration of toluene gives a mixture of *o*- and *p*-nitrotoluenes.	The nitro group is *m*-directing.
13. Contrary to the Saytzeff rule, the reaction of $Me_3C\text{—}CH_2\text{—}\overset{\displaystyle Me}{\overset{\vert}{\underset{\displaystyle Me}{\underset{\vert}{C}}}}\text{—}Br$ with sodium ethoxide gives $Me_3C\text{—}CH_2\text{—}\overset{\displaystyle Me}{\overset{\vert}{C}}{=}CH_2$ as the major product.	Normally the elimination of HX from an alkyl halide gives an alkene as per the Saytzeff rule. However, due to steric reasons a non-Saytzeff product may be obtained.

14. The diazotization of 1-aminobutane followed by warming with water gives 1-butanol as the major product.

The diazotisation of 1-aminobutane produces 1°-carbocation, which is rearranged to the more stable 2°-carbocation.

15. The Beckmann rearrangement of the oxime



gives RCONHR′.

In a Beckmann rearrangement, the migrating group is always syn (i.e., cis) to the hydroxyl group.

16. The Cannizzaro reaction of C_6H_5CHO and HCHO gives C_6H_5COOH and CH_3OH.

In the crossed Cannizzaro reaction of CH_2O with aldehydes without α-hydrogen, CH_2O is oxidized and the other group is reduced.

17. *p*-Dimethylaminobenzaldehyde does not undergo a Cannizzaro reaction.

A Cannizzaro reaction depends on the nucleophilic attack on the carbonyl carbon. So factors which reduce the positive charge on the carbonyl carbon retard the reaction. In extreme cases the reaction may not occur.

18. On being heated, 2,4,6-trimethylphenol allyl ether gives 3-allyl-2,4,6-trimethyl phenol.

The Claisen rearragement of aryl allyl ethers give the corresponding *o*-allylphenols. If both the *o*-positions are occupied, a *p*-product is obtained. Migration to the *m*-position is not possible.

19. Benzaldehyde does not undergo aldol condensation.

In aldol condensation it is necessary for the aldehyde to have an α-hydrogen, since the reaction involves the formation of carbanion.

20. On being heated with strong NaOH, $C_6H_5CHO + CH_3CHO$ gives $C_6H_5CH{=}CHCHO$.

In a Cannizzaro reaction, a strong alkali is used at high temperature, whereas in a Claisen reaction, a dilute alkali is used at room temperature.

21. The addition of HBr to $NCCH{=}CH_2$ gives $NC{-}CH_2{-}CH_2Br$ as the major product contrary to the expected $NCCH(Br)CH_3$.

Due to the strong electron-withdrawing effect of the CN group, in propene nitrile the secondary carbocation is less stable than the primary carbocation.

22.	Cyclo-octatetraene is said to be an aromatic compound.	Conjugated aromatic hydrocarbons containing $(4n+2)\pi$ electrons are aromatic while those containing $4n\pi$ electrons are antiaromatic or nonaromatic.
23.	The S_N2 reaction of *cis*-3-methylcyclopentyl bromide gives *cis*-3-methylcyclopentanol.	In S_N2 reactions, there is an exclusive attack from behind.
24.	On treatment with concentrated H_2SO_4, tert. butyl alcohol does not give ditertiary butyl ether; instead it gives 2-methyl propene.	On reaction with concentrated H_2SO_4, tertiary alcohols do not give ethers due to the instability of ethers formed in H_2SO_4 and also due to steric crowding.
25.	On being heated with *n*-butanol in the presence of sodium butoxide (n-C_4H_9ONa), ethylacetate gives *n*-butylacetate.	In trans esterification the alkyl group of one ester is replaced by the alkyl group of another alcohol.
26.	Aliphatic as well as aromatic amines can be prepared with equal ease by making potassium phthalimide react with alkyl or aryl halides followed by hydrolysis.	The halogen in aryl halides is inert compared to alkyl halides in nucleophilic displacements.
27.	Aliphatic amines are weaker bases than pyridine.	In pyridine the nitrogen atom is in the sp^2 state and so retains a greater hold on the unshared pair of electrons than the nitrogen atom in an aliphatic amine, where it is in the sp^3 state of hybridization.
28.	The basic strength of *m*-nitroaniline is more than that of *p*-nitroaniline.	The nitrogen atom in a primary amine is sp^3-hybridized.
29.	Guanidine is a much stronger base than other amines.	Guanidine is stabilized by resonance and a very strong base.
30.	*N*,*N*-2,6-Tetramethylaniline has more base strength than *N*,*N*-dimethylaniline.	The steric inhibition of o,o-disubstituted anilines increases the base strength of amines.
31.	Arenediazonium salts are much more stable than their aliphatic counterparts.	In arenediazonium salts there is resonance, i.e., dispersal of positive charge on the benzene ring.

32. Some alcohols are poured in small quantity in the fuel tanks of automobiles, particularly in cold countries.

The moisture present in gasoline gets dissolved in the alcohol, and therefore, does not freeze.

33. Tetrachloroethene has zero dipole moment.

The dipole moment arises from the highly polar carbon–chlorine bond.

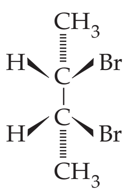
34. The acetate ion is a weaker base than the ethoxide ion.

In carboxylic acids, the carbonyl group is polarized and so the carbon of the carbonyl group bears a positive charge.

35. Isopropyl benzene can be oxidized by $KMnO_4$ to give benzoic acid but tertiary butyl benzene is resistant to oxidation by $KMnO_4$.

For the oxidation of the side-chain in benzene it is essential that a hydrogen atom be present in the α-position (benzylic position).

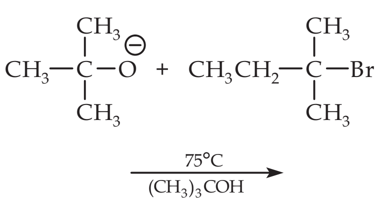
36. The structure

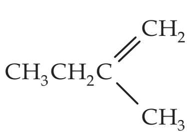


has two asymmetric carbon atoms but does not show optical activity.

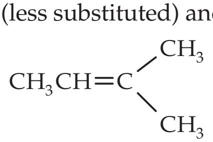
The meso compounds are optically inactive.

37. The major product obtained in the reaction



is 

(less substituted) and not



(more substituted).

The dehydrohalogenation of an alkyl halide by a base (e.g. C_2H_5ONa) gives a more substituted olefine (as per Saytzeff's rule). However dehydrohalogenation with a bulky base (e.g., tertiary butoxide) gives a less substituted olefine as the major product.

38. The S_N2 reaction of sodium alkylide $(RC{\equiv}\overset{-}{C}:\overset{+}{Na})$ with a 2° alkyl halide

$$R_1{-}CH_2{-}\underset{}{\overset{\displaystyle R_2 \atop |}{CH}}{-}Br$$

gives a mixture of $RC{\equiv}CH$ and $R_1{-}CH{=}CHR_2$ instead of the expected

$$RC{\equiv}C{-}\overset{\displaystyle R_1 \atop |}{CH}{=}CH{-}R_2.$$

In case of the 1° alkyl halide, the sodium alkynide acts as a nucleophile. However in case of the 2° or 3° alkyl halide, the sodium alkynide acts as a base.

39. The reaction of methyl magnesium bromide (1 mole) with 4-hydroxy-2-butanone $(HOCH_2{-}CH_2\underset{\displaystyle \| \atop O}{C}{-}CH_3)$ does not give the expected

$$HOCH_2{-}CH_2{-}\overset{\displaystyle CH_3 \atop |}{\underset{\displaystyle | \atop OMgBr}{C}}{-}CH_3.$$

Instead the product obtained is $BrMgOCH_2CH_2\underset{\displaystyle \| \atop O}{C}CH_3$.

Grignard reagents do not react with carbonyl compounds containing a hydroxyl group, since the OH group is much more reactive than the CO group.

40. The resonance structure of

$$H{-}\overset{\displaystyle H \atop |}{\underset{\displaystyle | \atop H}{C}}{-}O{-}H \text{ is } H{-}\overset{\displaystyle H \atop |}{\underset{\displaystyle | \atop H}{C}}{=}\overset{+}{\underset{\cdot\cdot}{O}}{-}H$$

Methanol cannot be represented by a resonance structure since the carbon atom has five bonds.

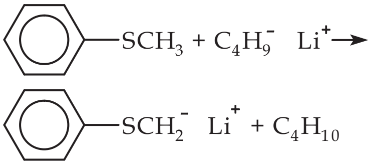
41. The chlorination of ethyl benzene in the presence of UV light gives 1-chloro-1-phenylethane as the major product.

In ethyl benzene, the 1° radical is more stable and formed more readily than the 2° radical.

42. Acetaldehyde is more reactive than acetone in nucleophilic substitution.

The positive charge on the carbonyl carbon in a ketone is more stable than that on the carbonyl carbon in an aldehyde. This is so because a ketone has two methyl groups and an aldehyde only one.

43. Thioanisole reacts with butyllithuim as follows.



However anisole does not undergo an analogous reaction.

The H atoms on C atoms that are adjacent to an alkylthio group are more acidic than those adjacent to an alkoxy group. So S atoms are easily polarized, and this can stabilize a negative charge on an adjacent atom.

44. Phenol is less acidic than 4-methylphenol.

The presence of an electron-releasing group in phenol makes it less acidic.

45. *o*-Hydroxybenzaldehyde can be separated from *p*-hydroxybenzaldehyde by steam distillation. *p*-Hydroxybenzaldehyde is obtained in the steam distillate.

o-Hydroxyaldehydes are steam volatile due to intramolecular H bonding.

46. On oxidation with mild oxidizing agents (e.g., atmospheric oxygen) thiols give disulphides.

The S–H bond is stronger than the O—H bond.

47. The reaction of $C_6H_5CO_2C_2H_5$ and $CH_3SO_2C_6H_5$ in the presence of C_2H_5ONa gives $C_6H_5COCH_2SO_2C_6H_5$.

In sulphones the hydrogens alpha to sulphur are acidic and undergo Claisen-type condensations with esters.

48. In general, N–H…N bonds are stronger than O–H…O and F–H…F bonds.

The electronegativity of nitrogen is less than that of oxygen or fluorine.

49. In cyclohexane, the boat conformation is more stable than the chair form.

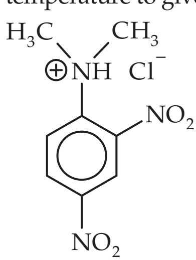
The instability of the boat form (in cyclohexane) relative to the chair form may be ascribed to relatively unfavourable interactions between the H atoms around the ring.

50. *cis-syn*. ditertiary butylethylene is stable compared to the trans form.

In *syn*. ditertiary butylethylene there is considerable steric hindrance between the bulky substituents.

51. The addition of bromine to an alkene gives a trans addition product.

The bromide ion attacks the carbon atom on the side opposite to the bridging group (viz., the bromonium ion).

52. Of CH_2O, CH_3CHO, CH_3COCH_3 and $(CH_3)_3C{-}\underset{\underset{O}{\Vert}}{C}{-}C(CH_3)_3$ the most unreactive carbonyl compound in an addition reaction is $(CH_3)_3C{-}\underset{\underset{O}{\Vert}}{C}{-}C(CH_3)_3$.	The reactivity of the carbonyl compound is greatly influenced by the bulkiness of the substituents.
53. The reactivity of cyclic ketones (e.g., cyclopentanone) is much less than that of open-chain analogues (e.g., 3-hexanone) during addition reactions.	In open-chain ketones, there is freedom of rotation of the groups attached to a C=O group. This causes greater steric hindrance in transition states during the addition process.
54. The nitration of benzoic acid gives *o*- and *p*-nitrobenzoic acid.	The COOH group in benzene deactivates the *o*- and *p*-positions more than the *m*-position.
55. The nitration of 2-methoxy acetanilide gives mainly the 4-nitro derivative.	If a benzene derivative contains OCH_3 and $NHCOCH_3$ (both being *o*- and *p*-directing), then $NHCOCH_3$ exerts a stronger influence than OCH_3.
56. Simple aryl halides (e.g., C_6H_5Cl) are inert to nucleophilic reagents, but 2,4-dinitrochlorobenzene reacts with $(CH_3)_2NH$ at room temperature to give 	The presence of strongly electron-attracting substituents (in *o*- and *p*-positions or both), activates the chloro group in 2,4-dinitrochlorobenzene.

Answers

1. d	**2.** d	**3.** a	**4.** b	**5.** d
6. c	**7.** a	**8.** d	**9.** a	**10.** d
11. a	**12.** d	**13.** a	**14.** d	**15.** c
16. d	**17.** a	**18.** d	**19.** a	**20.** d
21. a	**22.** d	**23.** d	**24.** a	**25.** a
26. d	**27.** d	**28.** b	**29.** a	**30.** a
31. a	**32.** a	**33.** b	**34.** b	**35.** a
36. a	**37.** d	**38.** a	**39.** a	**40.** d
41. c	**42.** a	**43.** a	**44.** d	**45.** d
46. c	**47.** a	**48.** d	**49.** d	**50.** d
51. a	**52.** a	**53.** d	**54.** d	**55.** a
56. a				

❑

Part 4

Miscellaneous Questions

1

Physical Chemistry Miscellaneous Questions

• *Type 1* •

Choose the correct option. Only one option is correct.

1. In the cell

$Zn(s) \mid Zn^{2+}(aq, 0.10\ M) \mid KCl(sat'd) \mid Zn^{2+}(aq, 1.0\ M) \mid Zn(s)$,

(a) $E°$ is not zero because the concentrations of the solutions in the left and right compartments are unequal

(b) $E°$ is zero because the same electrode and the same type of ions are involved

(c) $E°$ is zero because the same electrode and the same type of ions are involved

(d) $E°$ is not zero because the same electrode and different concentrations of ions are involved

2. 25 mL of $\frac{1}{10}$ N HCl will exactly neutralize (given that the atomic weight of boron is 10.8)

(a) 0.2728 g of $Na_2B_4O_7{\cdot}10H_2O$ (b) 0.4768 g of $Na_2B_4O_7{\cdot}10H_2O$

(c) 0.0604 g of $Na_2B_4O_7{\cdot}10H_2O$ (d) 0.8006 g of $Na_2B_4O_7{\cdot}10H_2O$

3. The reaction between NO_2 and CO to produce NO and CO_2 is believed to occur in the following two steps.

Step 1: $2NO_2 \longrightarrow NO + NO_3$

Step 2: $NO_3 + CO \longrightarrow NO + CO_2$

The intermediate product and the rate-determining step are

(a) NO and Step 1 (b) NO and Step 2

(c) NO_3 and Step 1 (d) NO_3 and Step 2

4. An orbial is

(a) a surface of constant probability density
(b) a one-electron spatial wave function
(c) a volume element in spherical polar coordinates
(d) a hydrogen atom in the ground state, the electron being confined to move within a sphere of fixed radius

5. Calculate the pH of a saturated 0.10-M H_2S solution (given that $K_1(H_2S) = 1 \times 10^{-7}$ mol L^{-1}, $K_2(H_2S^-) = 1 \times 10^{-14}$ mol L^{-1}).

(a) 7.0 (b) 1.0 (c) 3.0 (d) 4.0

6. Which of the following equations represents Boyle's law?

(a) $\frac{dp}{p} = -\frac{dV}{V+p}$ (b) $\frac{dp}{p} = -\frac{dV}{V}$
(c) $\frac{dp}{p+V} = -\frac{dV}{V+p}$ (d) $\frac{dp}{p} = \frac{dV}{V}$

7. Which of the following nuclear processes are identical?

(a) β^+ emission and β^- emission
(b) α emission and γ radiation
(c) β^+ emission and electron capture
(d) γ radiation and production of X-rays

8. Among the following, which is the most acidic?

(a) $IO(OH)_5$ (b) $B(OH)_3$
(c) CH_3CO_2H (d) HOCl

9. A d shell containing 5 electrons of parallel spin can exchange

(a) 10 electrons (b) 6 electrons
(c) 5 electrons (d) 25 electrons

10. Which of the following is an efficient catalytic converter?

(a) A reagent which oxidizes CO and unburnt hydrocarbons to CO_2 and H_2O, and reduces NO and NO_2 to N_2 and O_2.
(b) A reagent which oxidizes CO and NO to CO_2 and N_2 respectively.
(c) A reagent which oxidizes CO and unburnt PbO to CO_2 and PbO_2, and reduces SO_2 to H_2S.
(d) A reagent which reduces unburnt hydrocarbons to CO, CO_2 and H_2O and oxidizes N_2 to NO and NO_2.

11. Which of the following is arranged in order of increasing strength of conjugate base?

(a) $CN^- < NH_3 < NH_2^- < OH^-$ (b) $NH_2^- < OH^- < CN^- < NH_3$
(c) $OH^- < NH_3 < NH_2^- < CN^-$ (d) $NH_3 < CN^- < OH^- < NH_2^-$

12. In the reaction

$$CaCO_3(s) + \text{heat} \rightleftharpoons CaO(s) + CO_2(g),$$

reducing the volume of the system will

(a) shift the equilbrium to the left

(b) shift the equilibrium to the right

(c) reduce the particle pressure of the gas

(d) increase the temperature of equilibrium

13. Bulbs A and B contain an aqueous solution and pure water respectively. The bulbs are connected, and dry air is passed through them for some time. The air passes first through Bulb A and then through Bulb B. If the vapour pressure of water is p_1° and that of the solution is p_1, the weight losses of the bulbs containing the solution and the solvent are directly proportional to

(a) p_1 and p_1°

(b) p_1 and $p_1 - p_1^\circ$

(c) p_1 and $p_1^\circ - p_1$

(d) $p_1^\circ + p$ and $p_1^\circ - p$

14. What is the unit of Q (reaction quotient)?

(a) $(\text{mol L}^{-1})^{\Delta n}$

(b) $(\text{L atm})^{\Delta n}$

(c) It is pressure- and temperature-dependent.

(d) Q does not have a unit as it is dimensionless.

15. A compound AB crystallizes in the cubic-close-packed zinc blende structure. Assuming that B ions occupy the lattice points, what fraction of the tetrahedral sites is occupied by A ions?

(a) 25%

(b) 50%

(c) 75%

(d) 33%

16. A gas undergoes constant-temperature expansion from 250 mL to 750 mL. What is the work done by the gas if it expands against a vacuum?

(a) $RT \ln \frac{750}{250}$

(b) $RT \ln \frac{250}{750}$

(c) 0 J

(d) $nRT \ln \frac{750}{250}$

17. Which of the following bonds is resistant to oxidizing agents like Cl_2 as well as to strong nucleophiles like OH^-?

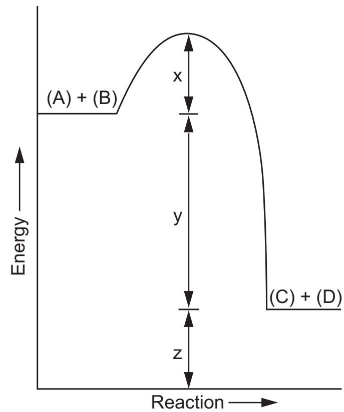
(a) C—Br

(b) C—I

(c) C—F

(d) C—O

18. The enthalpy change of the reaction (A) + (B) $\rightarrow$ (C) + (D) is y, as shown in the following figure.



The activation energy of the reaction (C) + (D) $\rightarrow$ (A) + (B) is represented by

(a) $x+y+z$ (b) $x+y$ (c) $x+y-z$ (d) $x-y+z$

19. Determine the S^{2-} concentration in a saturated H_2S solution to which enough HCl has been added to obtain an H^+ concentration of 1×10^{-3} mol L^{-1} (given that $K_1(H_2S) = 1.0 \times 10^{-7}$ mol L^{-1} and $K_2(HS^-) = 1.0 \times 10^{-14}$ mol L^{-1}).

(a) 1×10^{-14} mol L^{-1} (b) 1×10^{-16} mol L^{-1}

(c) 1×10^{-10} mol L^{-1} (d) 1×10^{-8} mol L^{-1}

20. 40.0 mL of a 0.03-M $KMnO_4$ solution will completely oxidize

(a) 30 mL of 0.15 M oxalic acid

(b) 20 mL of a 0.20-M ferrous oxalate solution

(c) 20 mL of a 0.10-M ferrous oxalate solution

(d) 25 mL of a 0.20-M Mohr salt solution

21. The coefficient of expansion for an ideal gas is given by $\alpha = \frac{1}{V}\left.\frac{dV}{dT}\right]_p$.

Using the ideal gas equation $pV = nRT$, we get

(a) $\alpha = \frac{1}{V}$ (b) $\alpha = \frac{1}{V}\left.\frac{dV}{dp}\right]_T$

(c) $\alpha = \frac{1}{p}$ (d) $\alpha = \frac{1}{T}$

22. A galvanic cell is set up according to the following specifications:

$$Zn(s) \mid Zn^{2+}(aq, 1\text{ M}) \mid KCl(\text{sat'd}) \mid Cu^{2+}(aq, 1\text{ M}) \mid Cu(s).$$

Choose the correct statement.

(a) During the overall redox reaction, electrons flow externally from the anode (Zn electrode) through the wire and voltmeter to the cathode (Cu electrode).

(b) In the solution, the cations (Zn^{2+}, Cu^{2+} and K^+) move towards the anode, while the anions (SO_4^{2-} and Cl^-) move towards the cathode.

(c) K^+ and Cl^- do not move to either electrode.

(d) The conductance of the saturated KCl solution is very low. So a KCl salt bridge is used.

23. The following data are given:

(i) $H_2(g) \longrightarrow 2H(g); \ \Delta H° = 436$ kJ

(ii) $Br_2(g) \longrightarrow 2Br(g); \ \Delta H° = 192$ kJ

(iii) $H_2(g) + Br_2(g) \longrightarrow 2HBr(g); \ \Delta H° = -104$ kJ

Then $\Delta H°$ for the reaction

$$H(g) + Br(g) \longrightarrow HBr(g)$$

is

(a) -376 kJ mol^{-1} (b) $+366$ kJ mol^{-1}

(c) -366 kJ mol^{-1} (d) -327 kJ mol^{-1}

24. The c/a ratio for the hexagonal close packing of a sphere is

(a) 1.363 (b) 1.633 (c) 1.732 (d) 1.414

25. An aqueous solution of $Mg(NO_3)_2$ is electrolysed. What are the gaseous products formed?

(a) O_2 at the anode and N_2 at the cathode

(b) N_2 at the anode and H_2 at the cathode

(c) O_2 at the anode and H_2 at the cathode

(d) N_2 at the anode and Mg at the cathode

26. Which of the following is arranged in the increasing order of acid strength?

(a) $HSO_3F < H_3O^+ < HSO_4^- < NH_3$

(b) $H_3O^+ < HSO_3F < NH_3 < HSO_4^-$

(c) $NH_3 < HSO_4^- < H_3O^+ < HSO_3F$

(d) $HSO_4^- < NH_3 < HSO_3F < H_3O^+$

27. How much ethylene glycol ($CH_2OH—CH_2OH$) must be added to 1.0 L of water so that the solution will not freeze at –20°C? (K_f for $H_2O = 1.86$ K kg mol^{-1})

(a) 66 g (b) 667 g (c) 1667 g (d) 333 g

28.

$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$
$$HCO_3^- \rightleftharpoons H^+ + CO_3^-$$
$$H_2O \rightleftharpoons H^+ + OH^-$$

For the above equations, which of the following is correct on the basis of the concept of electroneutrality?

(a) $3[H^+] = 2[HCO_3^-] + [CO_3^{2-}] + [OH^-]$

(b) $[H^+] = [HCO_3^-] + 2[CO_3^{2-}] + [OH^-]$

(c) $[H^+] = [HCO_3^-] + [CO_3^{2-}] + [OH^-]$

(d) $3[H^+] = [HCO_3^-] + 2[CO_3^{2-}] + [OH^-]$

29. The emf of a cell is

(a) dependent on the volume of the solution and the size of the electrodes

(b) independent of the volume of the solution and the size of the electrodes

(c) independent of the volume of the solution and depends on the size of the electrodes

(d) dependent on the volume of the solution and independent of the size of the electrodes

30. A possible mechanism for the reaction

$$2NO + 2H_2 \longrightarrow N_2 + 2H_2O$$

is

(i) $2NO \rightleftharpoons N_2O_2$
(ii) $N_2O_2 + H_2 \longrightarrow N_2O + H_2O$ (slow step)
(iii) $N_2O + H_2 \longrightarrow N_2 + H_2O$

The rate law for the reaction is

(a) $k[NO]^2[H_2]^{1/2}$ (b) $k[NO][H_2]^2$

(c) $k[NO]^2[H_2]$ (d) $k[NO]^2[H_2]^2$

31. What is the concentration of the acetic acid which is added to 0.5 N HCOOH so that the percentage dissociation of both the acids is unchanged (given that $K_a(CH_3COOH) = 1.8 \times 10^{-5}$ mol L^{-1} and $K_a(HCOOH) = 2.4 \times 10^{-4}$ mol L^{-1})?

(a) 6.1 mol L^{-1} (b) 0.62 mol L^{-1}

(c) 6.7 mol L^{-1} (d) 7.6 mol L^{-1}

32. The diamond atom may be viewed as

(a) two fcc structures displaced from each other by a quarter of the body diagonal

(b) two fcc structures displaced from each other by half the body diagonal

(c) four fcc structures displaced from each other by a quarter of the body diagonal

(d) four fcc structures displaced from each other by three-fourths of the body diagonal

• Type 2 •

Choose the correct options. More than one option is correct.

33. Which of the following are correctly matched?

(a) Interstitial defect $\leftrightarrow$ an extra atom in an interstitial site

(b) Schottky defect $\leftrightarrow$ an atom missing from an expected site

(c) Frenkel defect $\leftrightarrow$ an atom displaced to an interstitial site, creating a vacancy nearby

(d) Grain boundary defect $\leftrightarrow$ a boundary between two crystals in a crystalline solid

34. Which of the following statements correspond to the Hund rule?

(a) The state of maximum multiplicity is the lowest.

(b) The electrons occupy equivalent orbitals singly, as far as possible, with parallel spin.

(c) For a given multiplicity, the state of minimum L is the lowest.

(d) The state of maximum multiplicity is given by $2s+1$ or $n+1$, where s = total spin and n = number of singly occupied orbitals.

35. Which of the following statements are correct?

(a) In case of diffusion, molecular flux is directly proportional to molecular speed.

(b) In case of effusion, molecular flux is inversely proportional to molecular speed.

(c) For both diffusion and effusion, $\Delta G°$ tends to decrease.

(d) Diffusion involves the effect of collisions between molecules, whereas effusion does not.

36. Which of the following statements are correct?

(a) All Brønsted bases are Lewis bases.

(b) A coordinate covalent bond is always formed in a Lewis-base reaction.

(c) All Lewis acids are Brønsted acids.

(d) All amphoteric hydroxides are insoluble in water.

37. Two ideal gases have the same initial pressure, volume and temperature. They expand to the same final volume, one adiabatically and the other isothermally. Find the correct statements.

(a) The final pressure is greater for the isothermal process.

(b) The work done by the gas is greater for the isothermal process.

(c) The final temperature is greater for the isothermal process.

(d) All these statements are incorrect.

38. Which of the following statements are correct?

(a) According to the collision theory, a reaction occurs when molecules collide with energy sufficient to break the bonds and initiate the reaction. This energy is called activation energy.

(b) The overall balanced equation for a reaction may be the sum of a series of simple reactions called elementary steps.

(c) Enzymes are catalysts occuring in nonliving systems.

(d) A catalyst lowers the activation energy for the forward as well as the reverse reaction.

39. Which of the following statements are correct?

(a) Covalent character increases with decreasing cation size.

(b) Covalent character increases with increase in anion size.

(c) Cations with a non–noble-gas configuration have a greater covalent character than those of the same size with a noble-gas configuration.

(d) Cations with a noble-gas configuration have a greater covalent character than those of the same size with a non–noble-gas configuration.

40. Which of the following reactions represent hydrolysis and not dissociation?

(a) $HCO_3^- + H_2O \rightleftharpoons OH^- + H_2CO_3$

(b) $HPO_4^{2-} + H_2O \rightleftharpoons H_2PO_4^- + OH^-$

(c) $H_2Gly^+ + H_2O \rightleftharpoons HGly + H_3O^+$

(d) $H_2PO_4^- + H_2O \rightleftharpoons HPO_4^{2-} + H_3O^+$

Answers

1. b	**2.** b	**3.** c	**4.** b	**5.** d
6. b	**7.** c	**8.** a	**9.** a	**10.** a
11. d	**12.** a	**13.** c	**14.** d	**15.** b
16. c	**17.** c	**18.** b	**19.** b	**20.** c
21. d	**22.** a	**23.** c	**24.** b	**25.** c
26. c	**27.** a	**28.** b	**29.** b	**30.** c
31. c	**32.** a	**33.** a, b, c	**34.** a, b, d	**35.** a, b, c, d
36. a, b, d	**37.** a, b, c	**38.** a, b, d	**39.** a, b, c	**40.** a, b, c

Hints to More-Difficult Problems

3. Here NO_3 is an intermediate product because it is cancelled in Step 2, and so Step 1 is the rate-determining step.

5. The pH of H_2S is calculated by considering the first step of dissociation of H_2S.

$$K_1 = \frac{[H^+][HS^-]}{[H_2S]} = \frac{[H^+]^2}{[H_2S]} \qquad (\because\ [H^+] = [HS^-]).$$

$$\therefore \qquad 10^{-7} = \frac{[H]^{+2}}{0.1} \Rightarrow [H^+]^2 = 10^{-8} \Rightarrow \text{pH} = 4.$$

7. Positron emission: $\quad {}^{A}_{Z}X \longrightarrow {}_{Z+1}^{A}Y + {}^{0}_{+1}e$

Electron capture: $\quad {}^{A}_{Z}X + {}^{0}_{+1}e \longrightarrow {}_{Z+1}^{A}Y$

In both the processes, we obtain the identical product ${}_{Z+1}^{A}Y$.

9. $^5C_2 = \dfrac{5!}{3!\,2!} = \dfrac{120}{6 \times 2} = 10.$

10. The conjugate acid of NH_2^- is weakly basic.

12. Apply Le Chatelier's principle.

13. The loss of weight in bulb A is proportional to the vapour pressure of the solution (p_1). The loss of weight in bulb B is proportional to the vapour pressure of the solvent ($p_1^\circ - p_1$).

14. In the expression of Q, all activity terms are taken at unit pressure (p° = 1 bar) or unit concentration ($c^\circ = 1$ mol L^{-1}).

21. We know that

$$pV = nRT.$$

Differentiating with respect to T, we get

$$p \left.\frac{\partial}{\partial T}\right]_p = nR.$$

We can work out α from this.

22. The process is the reverse of that in the electrolytic cell.

23. Performing (iii) – (i) – (ii), we obtain

$$\Delta H^\circ = -104 \text{ kJ} - 436 \text{ kJ} - 192 \text{ kJ} = -732 \text{ kJ}$$

for the reaction $2H(g) + 2Br(g) = 2HBr(g)$.

$\therefore$ for the reaction $H(g) + Br(g) = HBr$,

$$\Delta H^\circ = \frac{-732 \text{ kJ mol}^{-1}}{2} = -366 \text{ kJ mol}^{-1}.$$

25. Water is electrolysed.

30. The slow step is the rate-determining step. So the rate of reaction is given by step (ii), i.e., then the rate law is $k[NO]^2[H_2]$.

31. According to the principle of isohydric solutions,

$$\frac{K_1}{V_1} = \frac{K_2}{V_2}.$$

Here, V_1 is the volume of HCOOH, V_2 is the volume of CH_3COOH, K_1 is the dissociation constant of HCOOH and K_2 is the dissociation constant of CH_3COOH.

$$[H^+]^2 = K_2[HCOOH] = 2.4 \times 10^{-4} \text{ mol L}^{-1} \times 0.5 \text{ mol L}^{-1}$$

$$= 1.2 \times 10^{-4} (\text{mol L}^{-1})^2.$$

$$[CH_3COOH] = \frac{[H^+]^2}{K_1} = \frac{1.2 \times 10^{-4} (\text{mol L}^{-1})^2}{1.8 \times 10^{-5} \text{ mol L}^{-1}} = 6.7 \text{ mol L}^{-1}.$$

40. In hydrolysis, an acid and a base are produced.

❑

2

Inorganic Chemistry Miscellaneous Questions

• *Type 1* •

Choose the correct option. Only one option is correct.

1. Which of the following alkali metals forms a peroxide in preference to a superoxide?

(a) K (b) Rb (c) Na (d) Cs

2. $CsI_3(s)$ is stable but $NaI_3(s)$ is not because

(a) large cations stabilize large unstable anions in CsI_3

(b) CsI_3 has a bcc structure and NaI_3 an fcc structure

(c) CsI_3 has a low hydration energy and NaI_3 a high hydration energy

(d) large cations stabilize small unstable anions in CsI_3

3. The temperatures at which ^1H_2O and D_2O have maximum density, respectively, are

(a) 4°C and 11.6°C (b) 11.6°C and 4°C

(c) 4°C and 12.5°C (d) 12.5°C and 4°C

4. Among the following, which is the strongest reducing agent?

(a) $[BH_4]^-$ (b) $[AlH_4]^-$

(c) $[GaH_4]^-$ (d) $[AlF_6]^{3-}$

5. Which of the following is arranged in order of increasing acidity?

(a) $N_2H_5^+ < NH_3OH^+ < NH_4^+$ (b) $NH_3OH^+ < NH_4^+ < N_2H_5^+$

(c) $NH_4^+ < N_2H_5^+ < NH_3OH^+$ (d) $NH_3OH^+ < N_2H_5^+ < NH_4^+$

6. Fluorine has a lower electron affinity than chlorine because

(a) there is greater electron–electron attraction in the F atom than in the larger Cl atom

(b) the standard reduction potential of $F_2|F^-$ is +2.87 V and that of $Cl_2|Cl^-$ is +1.36 V

(c) there is greater electron–electron repulsion in the F atom than in the larger Cl atom

(d) fluorine has an oxidation number of –1, and chlorine has a maximum oxidation number of +7

7. The action of sodium vapour on molten KCl at 850°C gives

(a) Cl_2 (b) K

(c) solvated electrons (d) solvated sodium ions

8. In the solid compound $K[Cu(CN)_2]$,

(a) two CN^- groups are bound through C, and the third (bridging) CN^- group through C and N

(b) three CN^- groups are bound through C, and the bridging CN^- group through C and N

(c) one CN^- group is bound through C, and the other through C and N

(d) one CN^- group is bound through C, and two other CN^- groups through C and N

9. Which of the following statements is incorrect?

(a) LiF is much less soluble than LiCl in water.

(b) AgF is much more soluble than AgCl in water.

(c) The structures of ZnO and HgO are quite different.

(d) The structures of HgF_2 and $HgCl_2$ are identical.

10. Which of the following statements is correct?

(a) In a semiconductor, the energy gap between the filled and the empty bands is much greater than in an insulator.

(b) In a metal, the energy gap between the conduction band and the valence band is greater than in an insulator.

(c) In an insulator, the valence band and the conduction band overlap.

(d) In an insulator, the energy gap between the valence band and the conduction band is considerably greater than in a metal.

11. Among the following molecules, which has the maximum dipole moment?

(a) O_3 (b) H_2O_2 (c) N_2H_4 (d) H_2O

12. The nuclear spins of protium, deuterium and helium-4 are respectively

(a) $\frac{1}{2}, 0, 2$ (b) $1, \frac{1}{2}, \frac{1}{2}$

(c) $\frac{1}{2}, 1, 0$ (d) $\frac{1}{2}, 1, 2$

13. Among the following hydrides, which is thermodynamically the most stable at room temperature?

(a) $BeH_2(s)$ (b) $LiH(s)$ (c) $B_2H_6(g)$ (d) $NaH(s)$

14. Which of the following reactions is used to prepare amorphous silicon?

(a) $Si_2H_6 \xrightarrow{400°C} (P)$

(b) $SiH_4 \xrightarrow{500°C} (P)$

(c) $SiH_4 \xrightarrow{\text{electric discharge}} (P)$

(d) $R_3SiCl + LiAlH_4 \longrightarrow (P)$

15. Which of the following is a mild reducing agent?

(a) SO_4^{2-} (b) $S_2O_3^{2-}$ (c) $S_2O_4^{2-}$ (d) $S_2O_6^{2-}$

16. Which of the following alkali metals forms a stable nitride?

(a) Li (b) Na (c) K (d) Cs

17. Which of the following statements is correct?

(a) The production of iron is basically a reduction process, and the conversion of iron to steel essentially an oxidation process in which the impurities in the iron are removed by oxygen gas.

(b) The production of iron and that of steel are both reduction processes.

(c) The production of iron is an oxidation process in which impurities are oxidized, and that of steel is a reduction process in which CO_2 is reduced to carbon.

(d) The production of iron and that of steel are both oxidation processes.

18. In $[Fe(CN)_6]^{3-}$, the d electrons occupy the

(a) d_{xy}, d_{yz}, d_{zx} and d_{z^2} orbitals

(b) d_{xy}, d_{yz}, and d_{zx} orbitals

(c) $d_{x^2-y^2}$ and d_{z^2} orbitals

(d) d_{xy}, d_{yz}, d_{zx}, $d_{x^2-y^2}$ and d_{z^2} orbitals

19. The complex ion $[Ni(CN)_2Br_2]^{2-}$ has a

(a) square-planar geometry (b) tetrahedral geometry

(c) square-pyramidal geometry (d) pyramidal geometry

20. H_2 is an excellent fuel for large rockets because of its

(a) low specific enthalpy (b) high specific enthalpy

(c) high bond energy (d) low electron affinity

21. Among the following reactions, which gives the highest proportion of ^{1}HD?

(a) $^{1}H_2 + D_2$ equilibrated over a platinum surface

(b) The reaction between D_2O and NaH

(c) The reaction between D_2O and NH_3

(d) The electrolysis of ^{1}HDO

22. The hydrolysis of Li_3N produces

(a) HN_3 (b) N_2H_4

(c) NH_2OH (d) NH_3

23. Which of the following is arranged in order of increasing ease of oxidation in air?

(a) $NO < N_2O < NO_2$ (b) $N_2O < NO_2 < NO$

(c) $NO_2 < NO < N_2O$ (d) $NO_2 < N_2O < NO$

24. Which of the following solid fluorides is unstable?

(a) LiF (b) CuF

(c) BeF_2 (d) HgF_2

25. Lithium is a highly active reducing agent because of its

(a) low ionization energy

(b) low sublimation energy

(c) strong metallic bonding

(d) very high hydration energy

26. In H_2O_2, the HOO angle is only 97° compared to the HOH bond angle of 104.5° in H_2O because the

(a) lone pair–bond pair repulsion is greater in H_2O_2 than in H_2O

(b) lone pair–bond pair repulsion is greater in H_2O than in H_2O_2

(c) bond pair–bond pair repulsion is greater in H_2O_2 than in H_2O

(d) bond pair–bond pair repulsion is greater in H_2O than in H_2O_2

27. Which of the following pairs give the same gaseous products upon treatment with water?

(a) NaN_3 and Li_3N (b) S_4N_4 and Li_3N

(c) CH_2N_2 and $(NH_4)_2Cr_2O_7$ (d) Na_2O_2 and KO_2

• Type 2 •

Choose the correct options. More than one option is correct.

28. Which of the following hydrated cations are colourless and diamagnetic?

(a) $Zn^{2+}(aq)$ (b) $Ti^{3+}(aq)$ (c) $Cu^{2+}(aq)$ (d) $Sc^{3+}(aq)$

29. Nitrogen reacts slowly with most compounds because of the

(a) high strength of the $N \equiv N$ bond

(b) high activation energy of N_2

(c) low polarizability of nitrogen

(d) high polarizability of nitrogen

30. Which of the following sets of species are isoelectronic?

(a) N_2, NO^+, CN^- (b) O_2^+, NO, N_2O

(c) O_2^{2-}, Cl_2, $N_2H_5^+$ (d) NO, NO_2^+, N_2O

31. Which of the following statements are correct?

(a) ClO_2 is an angular radical.

(b) The I_2O_5 molecule has an oxo-bridge between two IO_2 structures.

(c) $HBrO_4$ is more acidic but less stable than H_5IO_6.

(d) In XeF_7^-, there are six electron pairs around Xe, and one is a lone pair.

32. Which of the following statements are correct?

(a) Xenon form a range of compounds with fluorine and oxygen.

(b) Helium 4 is radioactive.

(c) Noble gases have positive electron affinities because their valence shells are full and an incoming electron occupies an orbital of a new shell.

(d) Noble gases have negative electron affinities because their valence shells are full and an incoming electron occupies an orbital of a new shell.

33. Which of the following statements are correct?

(a) A metal is an array of positive ions immersed in a sea of delocalized valence electrons.

(b) The strength of a metallic bond is due to the cohesive force resulting from delocalized electrons.

(c) The valence band and the conduction band in a metal are adjacent to each other.

(d) An electron can travel freely through a metal since the conduction band is devoid of electrons.

34. Which of the following statements are correct?

(a) In Al_2Cl_6, each aluminium atom is sp^3-hybridized.

(b) In Al_2Cl_6, each of the bridging chlorine atoms forms a normal covalent bond with one aluminium atom and a coordinate covalent bond with another.

(c) The reaction of Fe_2O_3(s) with Al(s) is endothermic.

(d) Alums are represented by the general formula $M^{+}M^{3+}(SO_4)_2 \cdot 12H_2O$.

35. The F—F bond is weak due to the

(a) strong repulsions between nonbonding electrons in the small F_2 molecule

(b) high standard reduction potential of fluorine

(c) presence of more electrons in the bonding molecular orbitals than in the antibonding molecular orbitals of F_2

(d) presence of more electrons in the antibonding molecular orbitals than in the bonding molecular orbitals of F_2

36. Which of the following are correctly matched?

(a) Barium hydride ↔ covalent hydride, molecular

(b) Silane ↔ covalent hydride, molecular

(c) Palladium hydride ↔ saline

(d) Arsane ↔ electron-rich, molecular

37. Which of the following can be prepared from PCl_5?

(a) $POCl_3$ (b) H_3PO_4

(c) $[PCl_4] [AlCl_4]$ (d) $N_3P_3Cl_6$

Answers

1. c	**2.** a	**3.** a	**4.** b	**5.** c
6. c	**7.** b	**8.** a	**9.** d	**10.** d
11. b	**12.** c	**13.** b	**14.** c	**15.** b
16. a	**17.** a	**18.** b	**19.** a	**20.** b
21. b	**22.** d	**23.** d	**24.** b	**25.** d
26. a	**27.** d	**28.** a, d	**29.** a, b, c	**30.** a, c
31. a, b, c	**32.** a, c	**33.** a, b, c, d	**34.** a, b, d	**35.** a, d
36. b, d	**37.** a, b, c, d			

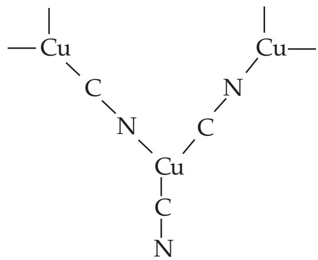
Hints to More-Difficult Problems

1. The least electropositive of these metals will polarize oxygen anions the least.

4. Among these anion complexes, $[AlH_4]^-$ is the strongest hydride donor.

7. Sodium is a more powerful reducing agent than potassium.

8. A portion of the spiral chain in $K[Cu(CN)_2]$ is



9. HgF_2 has a fluorite structure whereas mercury(II) chloride has a molecular lattice consisting of discrete linear $HgCl_2$ molecules.

11. H_2O_2 is more polar than the rest of the molecules shown. This can be vectorically worked out from their structures.

12. (i) Nuclei with p and n even (charge and mass even) have zero spin (e.g., helium-4).

(ii) Nuclei with p and n odd (charge odd and mass even) have integral spin (e.g., deuterium).

(iii) Nuclei with odd mass have half-integral spin (e.g., hydrogen).

16. Polarization effect

18. Fe is in the +III oxidation state in $[Fe(CN)_6]^{3-}$.

Its configuration is $3d^5$ or

↑	↑	↑	↑	↑
d_{xy}	d_{yz}	d_{zx}	$d_{x^2-y^2}$	d_{z^2}

.

CN^- is a strong ligand. So the electrons get paired and occupy the d_{xy}, d_{yz}, and d_{zx} orbitals in $[Fe(CN)_6]^{3-}$.

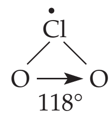
↑↓	↑↓	↑		
d_{xy}	d_{yx}	d_{zx}		

22. NH_3 is produced due to the protonation of the nitride ion, a Brønsted base.

24. Solid CuF disproportionates, forming Cu and CuF_2.

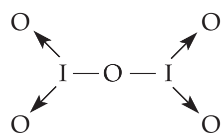
28. Zn^{2+}(aq) has a d^{10} electronic configuration and so cannot produce d–d spectra. Thus many of its compounds are colourless and diamagnetic. Sc^{3+}(aq) has a d^0 configuration and cannot produce d–d spectra either. Therefore, these ions and their compounds are also colourless and diamagnetic.

31.



is an angular radical.

The structure of I_2O_5 is

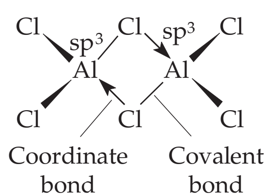


Again,

$$HBrO_4 \longrightarrow H^+ + BrO_4^- \text{ (acidic)}.$$

$H_5IO_6(HIO_4{\cdot}2H_2O)$ is known as paraperiodic acid. It is stable because of its tetrahedral constituent IO_4^-.

34. Potash alum $[K_2SO_4{\cdot}Al_2(SO_4)_3{\cdot}24H_2O]$, chrome alum $[K_2SO_4{\cdot}Cr_2(SO_4)_3{\cdot}24H_2O]$ and ferric ammonium alum $[(NH_4)_2SO_4{\cdot}Fe_2(SO_4)_3{\cdot}24H_2O]$ may be represented by the general formula $M^+M^{3+}(SO_4)_2{\cdot}12H_2O$.



Structure of Al_2Cl_6

❑

3

Organic Chemistry Miscellaneous Questions

• *Type 1* •

Choose the correct option. Only one option is correct.

1. With change in the hybridization of the carbon bearing the charge, the stability of a carbanion decreases in the order

(a) $sp < sp^2 < sp^3$ (b) $sp^3 < sp^2 < sp$

(c) $sp < sp^3 < sp^2$ (d) $sp^2 < sp < sp^3$

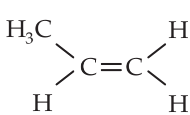
2. The order of stability of alkyl, vinyl and alkynyl carbanions is

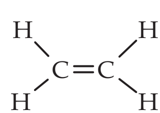
(a) $R\overset{-}{C}H_2 > RCH{=}\overset{-}{C}H > RC{\equiv}\overset{-}{C}$ (b) $RCH{=}\overset{-}{C}H > RC{\equiv}\overset{-}{C} > R\overset{-}{C}H_2$

(c) $RC{\equiv}\overset{-}{C} > RCH{=}\overset{-}{C}H > R\overset{-}{C}H_2$ (d) $R\overset{-}{C}H_2 > RCH{=}\overset{-}{C}H > RC{\equiv}\overset{-}{C}$

3. Which of the following alkenes is the most stable?

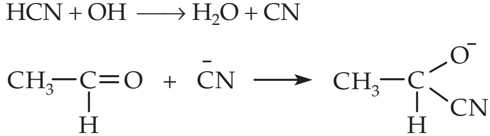
(a) $(CH_3)_2C{=}C(CH_3)_2$ (b) $(CH_3)_2C{=}CHCH_3$

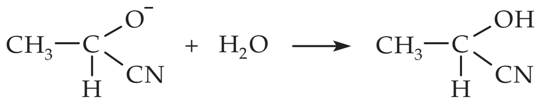
(c) 

(d) 

4. In the reaction of CH_3CHO with HCN in the presence of a base, the rate-determining step is

(a) $HCN + \overset{-}{O}H \longrightarrow H_2O + \overset{-}{C}N$

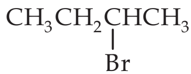
(b) 

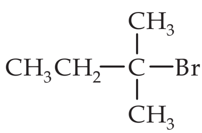
(c) 

(d) All the steps take place with equal ease.

5. Which of the following alkyl halides can be hydrolysed easily by an S_N2 reaction?

(a) $CH_3CH_2CH_2CH_2Br$

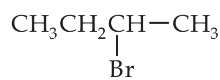
(b) 

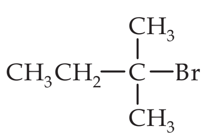
(c) 

(d) All are hydrolysed with equal ease.

6. Which of the following alkyl halides will be the most reactive in an S_N1 reaction?

(a) $CH_3CH_2CH_2CH_2Br$

(b) 

(c) 

(d) All are equally reactive.

7. The rate of the conversion

$$C_6H_5CH_2Cl \xrightarrow{KCN} C_6H_5CH_2CN$$

can be increased by carrying out the reaction

(a) in an aqueous solution by vigorous stirring

(b) in the presence of an acid catalyst

(c) by stirring in an aqueous medium in the presence of a small amount of tetrabutyl ammonium chloride

(d) by none of these methods

8. In the elimination reactions of appropriate substrates, the formation of the least-substituted alkane is explained by

(a) the Saytzeff rule

(b) the Hofmann rule

(c) both (a) and (b)

(d) neither (a) nor (b)

9. The major product obtained in the reaction

$$C_6H_5-\overset{\overset{\displaystyle O}{\|}}{C}-\overset{\overset{\displaystyle CH_3}{|}}{C}HCH_3 + D_2O \xrightarrow[\text{room temperature}]{OD^-} \text{products}$$

is

(a) $C_6H_5-\overset{\overset{\displaystyle O}{\|}}{C}-\overset{\overset{\displaystyle CD_3}{|}}{C}HCH_3$

(b) $C_6H_5-\overset{\overset{\displaystyle O}{\|}}{C}-\overset{\overset{\displaystyle CD_3}{|}}{C}DCD_3$

(c) $C_6H_5-\overset{\overset{\displaystyle O}{\|}}{C}-\overset{\overset{\displaystyle CH_3}{|}}{C}D-CH_3$

(d) none of these

10. In which of the following is the enol tautomer expected to be more predominant than the keto tautomer?

(a) 3-Pentanone
(b) Propanone
(c) Cyclohexanone
(d) 2,4-Pentanedione

11. What is the major product obtained in the following reaction?

$$CH_3CH{=}CHCO_2C_2H_5 \xrightarrow[C_2H_5OH,\ CH_3COOH]{NaCN} \text{products}$$

(a) $CH_3CH_2\underset{\underset{\displaystyle CN}{|}}{C}HCO_2C_2H_5$

(b) $CH_3CH{=}CHCO_2CN$

(c) $CH_3CH{=}CHCN$

(d) $CH_3\underset{\underset{\displaystyle COOH}{|}}{C}HCH_2CO_2C_2H_5$

12. What is the final product obtained in the reaction of

$$CH_3-\overset{\overset{\displaystyle O}{\|}}{C}-OC_2H_5$$

with an excess of Na in the presence of xylene (heating), followed by acidification with acetic acid?

(a) $\begin{array}{l} CH_3-C{=}O \\ \qquad\ \ | \\ CH_3-C{=}O \end{array}$

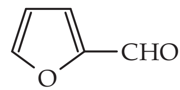
(b) $\begin{array}{l} CH_3-C-ONa \\ \qquad\ \ \| \\ CH_3-C-ONa \end{array}$

(c) $\begin{array}{l} CH_3-C{=}O \\ \qquad\ \ | \\ CH_3-C-OH \\ \qquad\ \ | \\ \qquad\ \ H \end{array}$

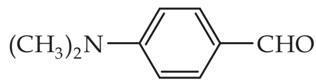
(d) None of these

13. Which of the following aldehydes does not undergo a Cannizzaro reaction?

(a) $C_6H_5—CHO$

(b) 

(c) $(CH_3)_2—CH—CHO$

(d) 

14. In the molecular-orbital model of benzene, how many π electrons are delocalized about the ring?

(a) Three (b) Four

(c) Five (d) Six

15. Cyclopentadiene is unusually acidic for a hydrocarbon. This is because

(a) the carbon atoms of cyclopentadiene are sp-hybridized

(b) cyclopentadiene is aromatic

(c) the removal of a proton from it yields an aromatic anion

(d) cyclopentadiene yields a highly stable free radical

16. The compound C_7H_{12} decolorizes bromine in CCl_4 and reacts with Ag^+ in ammonia to form an insoluble salt. On reduction in the presence of Ni, it gives 3-methylhexane. The most likely structure of the compound is

(a) $CH_3CH_2\underset{\displaystyle CH_3}{\underset{|}{C}}=CH-CH=CH_2$

(b) $CH_3CH_2\underset{\displaystyle CH_3}{\underset{|}{C}}HCH_2C\equiv CH$

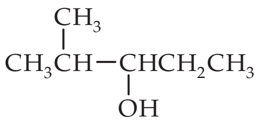
(c) $CH_3CH=\underset{\displaystyle CH_3}{\underset{|}{C}}-CH=CHCH_3$

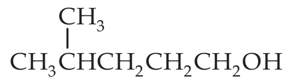
(d) $CH_3CH_2\underset{\displaystyle CH_3}{\underset{|}{C}}HC\equiv C-CH_3$

17. Which of the following alcohols will initially form the most stable carbocation on treatment with concentrated H_2SO_4?

(a) $CH_3CH_2-\overset{\displaystyle CH_3}{\overset{|}{\underset{\displaystyle OH}{\underset{|}{C}}}}-CH_2CH_3$

(b) $CH_2OH-\overset{\displaystyle CH_3}{\overset{|}{C}}H-CH_2CH_2CH_3$

(c) 

(d) 

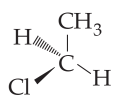
18. The product (P) of the reaction

$$CH_3Li + D_2O \longrightarrow (P)$$

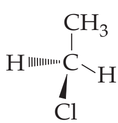
is

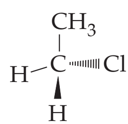
(a) CH_3OD (b) $CH_3—CH_3$

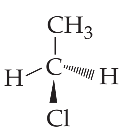
(c) CH_3D (d) $CH_3—O—CH_3$

19. 

Which of the following is an enantiomer of the above structure?

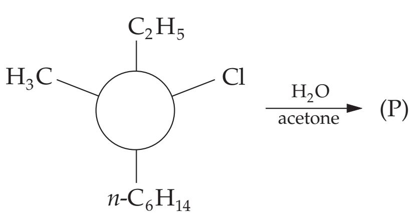
(a) 

(b) 

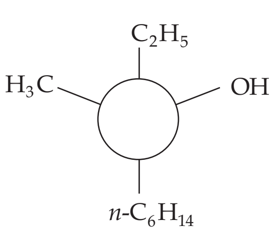
(c) 

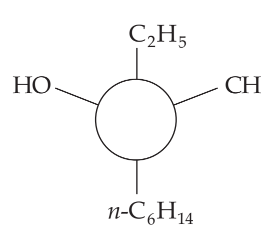
(d) It does not have an enantiomer.

20. The product (P) obtained in the reaction



is

(a) 

(b) 

(c) a mixture of (a) and (b) (d) none of these

21. In a nucleotide unit, the components of which of the following are sequentially linked?

(a) Monosaccharide–phosphate–heterocyclic base
(b) Amino acid–monosaccharide–phosphate
(c) Monosaccharide–amino acid–phosphate
(d) None of these

22. The transfer RNA anticodon for the messenger RNA codon G–C–A is

(a) G–C–U (b) U–G–C
(c) C–G–U (d) G–U–C

23. The monomeric units of nucleic acids are

(a) D-ribose or 2-dioxy-D-ribose molecules
(b) nucleosides
(c) nucleotides
(d) all of these

24. The secondary structure of a protein is derived from

(a) peptide linkages (b) disulphide linkages
(c) hydrogen-bond formation (d) none of these

• *Type 2* •

Choose the correct options. More than one option is correct.

25. Which of the following statements are correct about the electromeric effect?

(a) It involves permanent polarization.
(b) It operates through π bonds.
(c) It is a strong effect since the loose π electrons shift completely.
(d) None of these is correct.

26. The intermediate products of the reaction

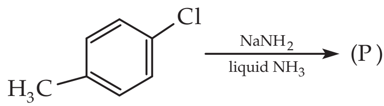
$$Me_2CH{-}CH{=}CH_2 \xrightarrow{HCl} Me_2CCl{-}CH_3{-}CH_3 + Me_2CH{-}\underset{\displaystyle Cl}{\underset{|}{CH}}{-}CH_3$$

are

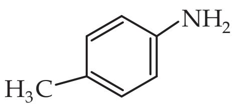
(a) $Me_2CH{-}\overset{+}{C}H{-}CH_3$ (b) $Me_2\overset{+}{C}{-}CH_2CH_3$

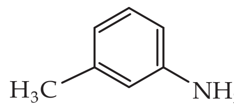
(c) $Me_2CH{-}CH_2{-}\overset{+}{C}H_2$ (d) none of these

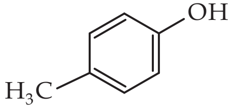
27. The products (P) obtained in the reaction

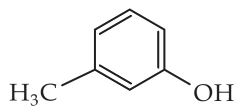


are

(a) 

(b) 

(c) 

(d) 

28. Which of the following is an example of nucleophilic addition?

(a) Ketal formation

(b) Reduction with hydrogen

(c) Cyanohydrin formation

(d) Bisulphite addition

29. The rate of the reaction

$$CH_3CH_2-\underset{\underset{CH_3}{|}}{\overset{\overset{H}{|}}{C}}-\overset{\overset{O}{\|}}{C}-C_6H_5 + Br_2 \xrightarrow{OH^-} (P)$$

is the same as that of

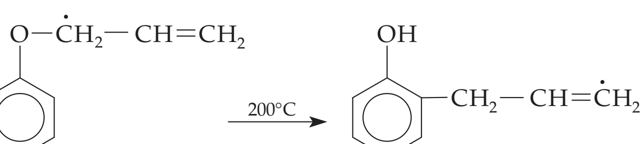
(a) racemization

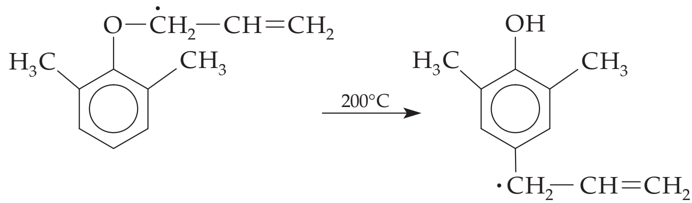
(b) chlorination

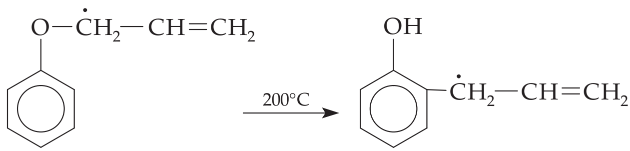
(c) protium–deuterium exchange at the alpha carbon

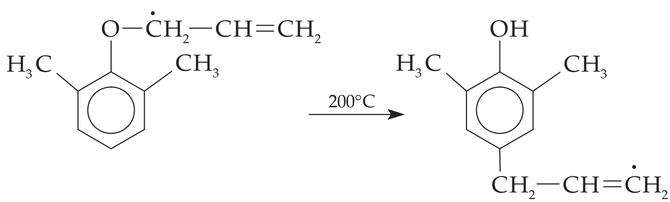
(d) iodination with I_2 and OH^-

30. Which of the following conversions are possible (• indicates a labelled carbon)?

(a) 

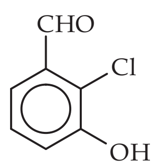
(b) 

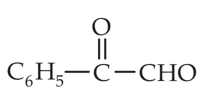
(c) 

(d) 

31. Which of the following aldehydes do not undergo the usual Cannizzaro reaction?

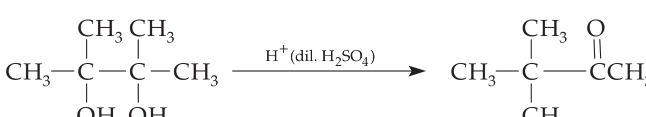
(a) 

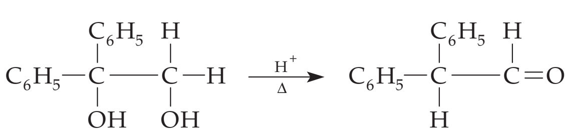
(b) 

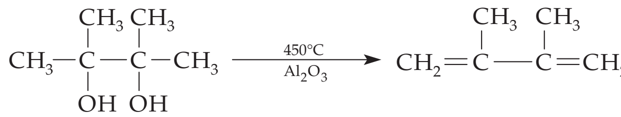
(c) 

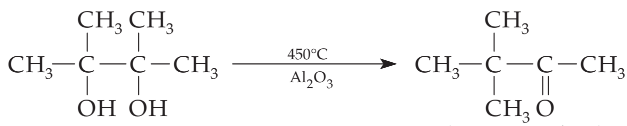
(d) 

32. Which of the following reactions are possible?

(a) 

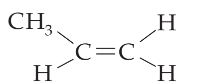
(b) 

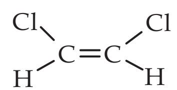
(c) 

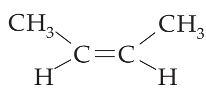
(d) 

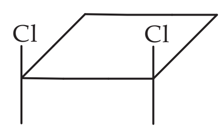
(major product)

33. Which of the following have *trans* isomers?

(a) 

(b) 

(c) 

(d) 

34. Which of the following statements are true for the S_N2 reaction of (*R*)-2-bromobutane with a hydroxide ion?

(a) The reaction occurs with inversion of configuration.

(b) The reaction occurs with retention of configuration.

(c) Doubling the concentration of the hydroxide ion doubles the rate of the reaction.

(d) Doubling the concentration of the substrate doubles the rate of the reaction.

35. The hydrogen bonding for the base pairs of DNA are between

(a) amide carbonyl and $—NH_2$

(b) amide NH and cyclic amine nitrogens

(c) alcohols and carbonyls

(d) There is no hydrogen bonding.

36. What are the products formed in the following reaction?

$$^{14}CH_2{=}CH{—}CH_3 \xrightarrow{N\text{-bromosuccinimide}} \text{products}$$

(a) $^{14}CH_2{=}CH{—}CH_2Br$

(b) $CH_2{=}CH{—}^{14}CH_2Br$

(c) $CH_2{=}CH{—}CH_2Br$

(d) None of these

37. Compare the compounds

$$\underset{\text{I}}{CH_3\overset{\overset{O}{\|}}{C}-S-CH_2CH_3} \quad \text{and} \quad \underset{\text{II}}{CH_3\overset{\overset{O}{\|}}{C}-O-CH_2CH_3},$$

and state which of the following statements are correct.

(a) II is more effectively stabilized than I.

(b) The α-hydrogens in I are more acidic than those in II.

(c) The C—O bond in II is stronger than the C—S bond in I.

(d) The C—O bond in II is weaker than the C—S bond in I.

Answers

1. a	**2.** c	**3.** a	**4.** b	**5.** a
6. c	**7.** c	**8.** b	**9.** c	**10.** d
11. d	**12.** c	**13.** d	**14.** d	**15.** c
16. b	**17.** a	**18.** c	**19.** d	**20.** c
21. d	**22.** c	**23.** c	**24.** c	**25.** b, c
26. a, b	**27.** a, b	**28.** a, c, d	**29.** a, b, c, d	**30.** a, b
31. c, d	**32.** a, b, c	**33.** b, c, d	**34.** a, c, d	**35.** a, b
36. a, b	**37.** a, b, c			

Hints to More-Difficult Problems

2. The sp-hybridized carbon atom of ethyne polarizes its C—H bonds to the greatest extent because it is the most electronegative. This causes its hydrogens to be the most positive. Therefore, ethyne donates a proton to a base more readily than the other groups do.

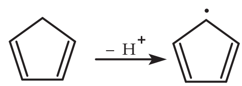
5. An S_N2 reaction proceeds through a five-membered transition state and such a transition state is destabilized by overcrowding at the central carbon atom.

7. Tetrabutyl ammonium chloride is a phase-transfer catalyst.

8. According to the Hofmann rule, in the elimination reaction of appropriate substrates, the least-substituted alkene is the major product.

9. Under basic conditions, only the protons at carbon atoms α to the carbonyl group are replaced by deuterium.

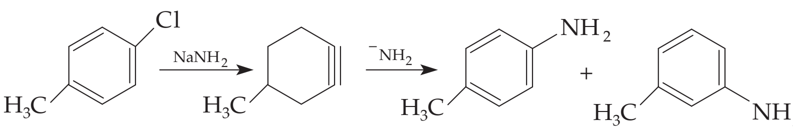
15.



After the removal of one proton (H^+) from cyclopentadiene, a pentadienyl anion is obtained. It has a 6π electron system and is, therefore, aromatic.

16. Decoloration with bromine in CCl_4 is a characteristic of unsaturated compounds. But the second reaction with Ag^+ to form an insoluble salt is possible only with terminal alkynes.

27. This is an example of nucleophilic aromatic substitution. Reactive intermediate benzyne is produced, followed by an attack by the nucleophile $^-NH_2$ at either position.



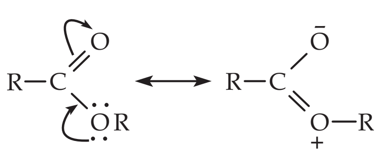
32. (a) and (b) are examples of methyl/hydride shift under acidic conditions but (c) is an example of just dehydration over a support at high temperature. Under these conditions, the methyl group is not transferred.

33. Geometrical isomerism is shown by compounds of the type abC=Cde.

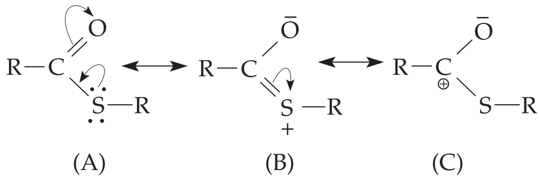
36. Both (a) and (b) are formed because *N*-bromosuccinimide is used for bromination at the allylic position, and the allylic radical formed in this reaction is resonance-stabilized.

$$^{14}CH_2{=}CH{-}CH_3 \rightleftharpoons {}^{14}CH_2{=}CH{-}\dot{C}H_2 \longleftrightarrow {}^{14}\underset{\cdot}{C}H_2{-}CH{=}CH_2$$

37. Sulphur is less electronegative than oxygen. The mesomeric effect of oxygen is greater than that of sulphur. Therefore, lone-pair electrons take part in resonance with a carbonyl group and make it less susceptible to a nucleophilic attack.



In contrast, thiol esters are not so effectively stabilized by a similar resonance contribution.



(A) requires an overlap between the 3p orbital of sulphur and a 2p orbital of carbon. Since this overlap is not large, resonance stabilization by (A) is not so effective.

In fact, (B) makes the carbonyl carbon atom more susceptible to a nucleophilic attack.

❑

Part 5

Practice Test Papers

Practice Test Papers

In the following pages, seven model test papers are provided with the following objectives:

(a) to assess your preparation,

(b) to develop your skills of time management, and

(c) to familiarize you with the actual examination-hall situation.

• *Instructions* •

The time for each test is 60 minutes. Each test paper contains 44–81 questions. You may attempt questions in any order within this time limit.

Each test paper contains 44–81 questions. Each question carries one mark. There is no negative marking.

Answers are provided after each test paper. Keep a separate blank sheet handy for your rough work. Do not use calculators, log tables or slide rules.

1

Practice Worksheet—1

• *Type 1* •

Choose the correct option. Only one option is correct.

1. $B(OH)_3$ is a weak acid. It can act as a strong base in the presence of

(a) sodium hydroxide (b) hydrochloric acid

(c) glycerol (d) any *trans* diol

2. Which of the following statements is correct?

(a) The B—F bond length in BF_3 is substantially less than the sum of the single-bond radii of B and F.

(b) NF_3 is highly reactive.

(c) BBr_3 is a poor electron acceptor compared to BF_3.

(d) The shapes of NO_2^+, NO_2 and NO_2^- are angular.

3. At room temperature, a blue gas (X) with a characteristic fishy odour can restore the colour of a blackened lead painting. The gas also bleaches in the absence of moisture and is used as a rocket fuel. The gas (X) is

(a) O_2 (b) NH_3 (c) O_3 (d) H_2

4. The vapour density of a mixture consisting of NO_2 and N_2O_4 is 38.3 at 300 K. Calculate the number of moles of NO_2 in 100 g of the mixture.

(a) 0.33 (b) 0.23 (c) 0.43 (d) 0.53

5. The positronium is a species consisting of an electron bound to a positron. Calculate its ionization potential.

(a) 13.6 V (b) 6.8 V (c) 27.2 V (d) 3.4 V

6. How many moles of barium hydroxide must be dissolved to produce 500 mL of an aqueous solution of pH = 12? (Assume complete dissociation of barium hydroxide.)

(a) 1.5×10^{-8} (b) 2.5×10^{-4} (c) 2.5×10^{-6} (d) 2.5×10^{-3}

7. The values of the solubility products at 25°C for the following salts are as given below:

(i) Ag_2CrO_4: 2.5×10^{-12} (mol $L^{-1})^3$

(ii) AgCl: 1.5×10^{-10} (mol $L^{-1})^2$

(iii) $Cr(OH)_3$: 1.0×10^{-30} (mol $L^{-1})^4$

(iv) $Mg(OH)_2$: 6.0×10^{-12} (mol $L^{-1})^3$

Then the solubility in mol L^{-1} is maximum for

(a) Ag_2CrO_4 (b) AgCl

(c) $Cr(OH)_3$ (d) $Mg(OH)_2$

8. Which of the following compounds is not easily hydrolysed?

(a) PCl_3 (b) $SnCl_4$ (c) NF_3 (d) AsF_3

9. In which of the following equilibrium reactions is the yielding of the product(s) not affected by the pressure applied?

(a) $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$

(b) $C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g)$

(c) $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$

(d) $NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$

10. Which of the following is correct for an NaCl crystal lattice?

(a) The centre-to-centre distance between two nearest oppositely charged ions is $\frac{1}{2}a$.

(b) The centres of two nearest like-charged ions are $\frac{1}{\sqrt{2}}a$ apart.

(c) The centres of two nearest like-charged ions are $\frac{\sqrt{3}}{2}a$ apart.

(d) The atomic positions of an NaCl crystal are

$$Cl^-: \left(\frac{1}{2}\ \frac{1}{2}\ \frac{1}{2}\right), \left(\frac{1}{2}\ \frac{1}{2}\ 0,\right) \left(\frac{1}{2}\ 0\ \frac{1}{2}\right), \left(0\ \frac{1}{2}\ \frac{1}{2}\right)$$

and

$$Na^+: \left(\frac{1}{2}\ \frac{1}{2}\ \frac{1}{2}\right), \left(0\,0\ \frac{1}{2}\right), \left(0\ \frac{1}{2}\ 0\right), \left(\frac{1}{2}\ 0\ 0\right).$$

11. Which of the following complexes does not obey the 18-electron rule (EAN rule)?

(a) $Ni(CO)_4$ (b) $[Cr(NH_3)_6]^{3+}$

(c) $[Fe(CN)_6]^{4-}$ (d) $[Co(NH_3)_6]^{3+}$

12. The hexagonal-close-packed (hcp) and cubic-close-packed (ccp) arrangements are described respectively as

(a) ABABAB… and ACBABCA…

(b) ABBABA… and ABCABCABC…

(c) ABABAB… and ABCABCABC…
(d) ABCACBAB… and ACBACBABAC…

13. A flask containing air at 27°C under the standard atmospheric pressure is corked. A pressure of 2.5 atm inside the flask would force the cork out. The temperature at which this will happen is

(a) 167 K (b) 677 K
(c) 750 K (d) 120 K

14. Which of the following complexes is a high-spin complex?

(a) $[Fe(CN)_6]^{4-}$ (b) $[Ni(CN)_4]^{2-}$
(c) $[Fe(C_2O_4)_3]^{3-}$ (d) $[Co(NH_3)_6]^{3+}$

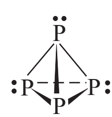
15. When a gas filled in a closed vessel is heated through 1°C, its pressure increases by 0.5%. The initial temperature of the gas was

(a) 100 K (b) 200 K (c) 300 K (d) 180 K

16. Red phosphorus is less reactive than white phosphorus because

(a) the P—P bond length is greater in red phosphorus
(b) red phosphorus exists as a polymeric structure
(c) red phosphorus is held by the van der Waals forces
(d) red phosphorus has more donor ability

17. Consider the tetrahedral P_4 molecule and identify the correct statement.



(a) The P—P distance is 2.21 Å and the P—P—P angle is 120°.
(b) The P—P—P angle indicates that it is a strained molecule having a strain energy of 6 kJ mol^{-1}.
(c) The lengths of the six P—P bonds in this molecule are smaller than the P—P bond lengths in other molecules containing multiple phosphorus atoms.
(d) None of these is correct.

18. Alumina is insoluble in water because

(a) it is a covalent compound
(b) it has a high lattice energy and a low enthalpy of hydration
(c) it has a low lattice energy and a high enthalpy of hydration
(d) Al^{3+} and O^{2-} ions are not excessively hydrated

19. When hydrated $MgCl_2{\cdot}6H_2O$ is strongly heated,

(a) MgO is formed (b) anhydrous $MgCl_2$ is formed
(c) Mg(OH)HCl is formed (d) Mg(OH)Cl is formed

20. Which of the following bases would give 1-alkene?

(a) $CH_3\underset{CH_3}{\overset{CH_3}{C}}O^-$

(b) $CH_3CH_2\underset{CH_2CH_3}{\overset{CH_2CH_3}{C}}O^-$

(c) $CH_3CH_2O^-$

(d) $CH_3CH_2\underset{CH_3}{\overset{CH_3}{C}}O^-$

21. Which of the following alkyl halides could be successfully used to form a Grignard reagent?

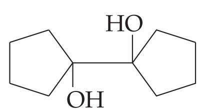
(a) $HOCH_2CH_2CH_2CH_2Br$

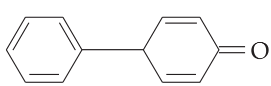
(b) $CH_3{-}\underset{CH_3}{N}{-}CH_2CH_2CH_2Br$

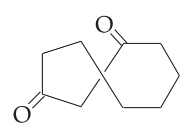
(c) $BrCH_2CH_2CH_2COOH$

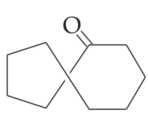
(d) $H_2NCH_2CH_2CH_2Br$

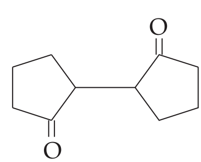
22. What product will be obtained when the *vicinal* diol shown below is heated in an acidic solution?



(a) 

(b) 

(c) 

(d) 

23. Which of the following have been arranged in the order of decreasing reactivity towards electrophilic substitution?

(a) Ethylbenzene > anisole > benzene > chlorobenzene

(b) 2,4-Dinitrophenol > 1-chloro-2,4-dinitrobenzene > 2,4-dinitrotoluene

(c) 2,4-Dinitrophenol > 2,4-dinitrotoluene > 1-chloro-2,4-dinitrobenzene

(d) *p*-Xylene > *p*-cresol > toluene

• Type 2 •

Choose the correct options. More than one option is correct.

24. Which of the following statements are false?

(a) The addition of HBr to an alkene is stereospecific.

(b) *meso* Compounds do not rotate polarized light.

(c) Diastereoisomers have the same melting point.

(d) The addition of HBr to an alkene is stereoselective.

25. Which of the following metal ions are precipitated as sulphides by passing H_2S gas in an ammoniacal medium?

(a) Cd^{2+} (b) Ni^{2+} (c) Pb^{2+} (d) Zn^{2+}

26. Which of the following compounds disproportionate?

(a) PbI_4 (b) FeI_3

(c) $Ca(ClO_3)_2$ (d) AuCl

27. Which of the following statements are correct about ethanenitrile?

(a) The C—N σ bond is formed using sp^2 hybrids of carbon and nitrogen, just as in ethene.

(b) The C—N σ bond is formed using sp hybrids of carbon and nitrogen, just as in ethyne.

(c) The second sp orbital of the nitrogen atom is occupied by a lone pair of electrons.

(d) The out-of-plane 2p orbitals form the two π bonds.

28. Indicate the correct statements.

(a) An electrochemical cell is an arrangement in which a chemical reaction does electrical work or in which electrical work is used to bring about a chemical reaction.

(b) The galvanic cell is an electrochemical cell that produces electricity as a result of spontaneous reactions occuring inside it.

(c) The electrolytic cell is an electrochemical cell in which a nonspontaneous reaction is driven by an external source of current.

(d) Salt bridge is a concentrated electrolytic solution of KNO_3/KCl/NH_4NO_3 in agar jelly that completes the electrical circuit between two electrical compartments.

29. The structure of rock salt (NaCl)

(a) consists of two mutually interpenetrating and slightly expanded face-centred-cubic (fcc) arrays of ions

(b) consists of two interpenetrating simple cubic arrays of ions—one of the cations and the other of the anions

(c) has radius ratios greater than 0.414 and less than 0.732

(d) has a 4 : 4 coordination

30. The reaction of $C_6H_5CH{=}CHCHO$ with $NaBH_4$ does not give

(a) $C_6H_5CH_2CH_2CH_2OH$ (b) $C_6H_5CH_2CH_2CHO$

(c) $C_6H_5CH{=}CHCH_2OH$ (d) $C_6H_5CH_2CHOHCH_3$

31. For the equilibrium

$$P + Q \underset{k_r}{\overset{k_f}{\rightleftharpoons}} A + B,$$

(a) $k_f[P]_{eq}[Q]_{eq} = k_r[A]_{eq}[B]_{eq}$

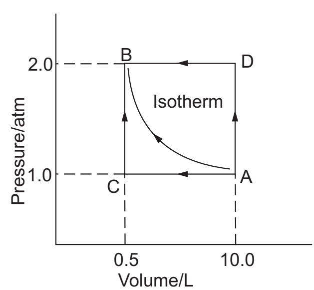
(b) $K = \dfrac{A_f}{A_r}\exp\left(\dfrac{-\Delta E}{RT}\right)$

(c) if ΔE is positive, an increase in temperature results in an increase in equilibrium constant

(d) $\Delta G^\circ = -RT\ln\dfrac{K}{Q}$

• *Comprehension-Type Questions* •

• Study the following graph, assuming perfect gas behaviour. Take $C_{V,m} = \dfrac{3}{2}R$ and $T = 313$ K.



32. The amounts of work done on the gas along the paths *ACB* and *ADB* are respectively

(a) -19.5×10^2 J and -2.9×10^4 J (b) -9.5×10^2 J and -1.9×10^4 J

(c) -1.9×10^4 J and -9.5×10^4 J (d) -9.5×10^2 J and -9.5×10^2 J

33. The work done on the gas along the isotherm *AB* is

(a) -4.0×10^3 J (b) 3.0×10^3 J

(c) 4.0×10^3 J (d) -3.0×10^3 J

34. The value of q for all the three paths will be

(a) 939 cal (b) 1565 cal (c) zero (d) infinity

• *Matching-Type Questions* •

Column A	Column B
35. $\dfrac{\Delta_{\text{mix}} S'}{R \sum_{i=1}^{N} x_i \ln x_i}$	(a) Third law of thermodynamics
36. $\lim_{T \to 0} C_{p,\,\text{m}}$	(b) V
37. $\left.\dfrac{\partial G}{\partial T}\right]_p$	(c) $\dfrac{C_V}{T}$
38. $\left.\dfrac{\partial G}{\partial p}\right]_T$	(d) Real gases
39. $\left.\dfrac{\partial S}{\partial T}\right]_V$	(e) $-S$
40. $\left.\dfrac{\partial T}{\partial p}\right]_H \neq 0$	(f) -1
41. $\Delta S \to 0$ as $T \to 0$	(g) Infinity

• *Numerical Problems* •

42. The element curium ($^{248}_{96}Cm$) has a mean life of 10^{13} seconds. Its primary decay modes are spontaneous fission and α-decay, the former with a probability of 8% and the latter with a probability of 92%. Each fission releases 200 MeV of energy. The masses involved in α-decay are as follows:

$$^{248}_{96}Cm = 248.072220 \text{ u}, \;\; ^{244}_{94}Pu = 244.064100 \text{ u and } ^{4}_{2}He = 4.002603 \text{ u}.$$

Calculate the power output in microwatts from a sample of 10^{20} Cm atoms (given that 1 u = 931 MeV/c^2).

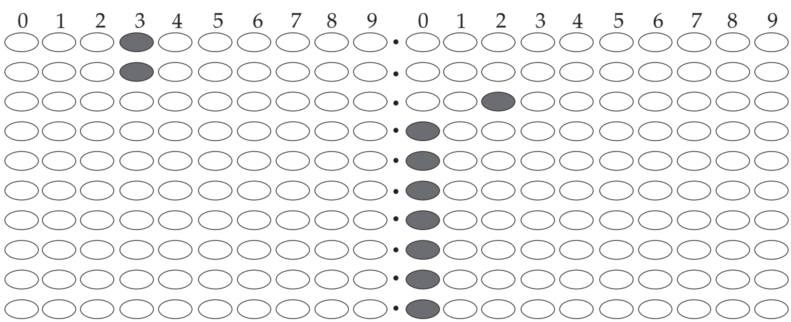
43. A hydrogen-like atom with the atomic number Z is in an excited state of the quantum number $2n$. It can emit a photon of 204 eV maximum energy. If it makes a transition to the quantum state n, a photon of 40.8 eV energy is emitted. After obtaining the values of n, Z and the ground-state energy (in eV) of this atom, calculate the minimum energy (in eV) that can be emitted by this atom during de-excitation. The ground-state energy of a hydrogen atom is given 13.6 eV.

44. A $KMnO_4$ solution is prepared by dissolving 1.185 g $KMnO_4$ in water and diluting it to 500 mL. How many millilitres of this will react with the iron in 0.500 g of an ore containing 36% of Fe_2O_3 by mass? The titration reaction takes place in an acidic medium.

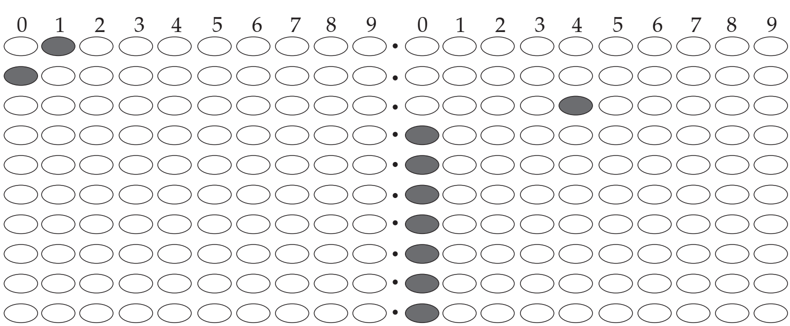
Answers

1. c	**2.** a	**3.** c	**4.** c	**5.** b
6. d	**7.** a	**8.** c	**9.** c	**10.** b
11. b	**12.** c	**13.** c	**14.** c	**15.** a
16. b	**17.** c	**18.** d	**19.** d	**20.** b
21. b	**22.** c	**23.** c	**24.** a, c, d	**25.** b, d
26. a, b, d	**27.** b, c, d	**28.** a, b, c, d	**29.** a, c	**30.** a, b, d
31. b, c				
32. b	**33.** d	**34.** c		
35. ↔ f	**36.** ↔ g	**37.** ↔ e	**38.** ↔ b	**39.** ↔ c
40. ↔ d	**41.** ↔ a			

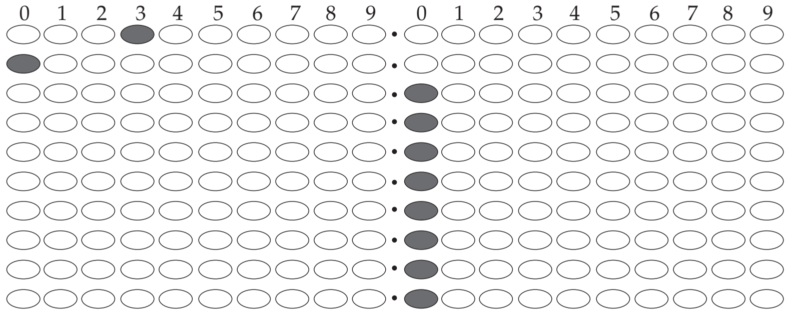
42. 33.2



43. 10.4



44. 30



Hints to More-Difficult Numerical Problems

42. The reaction involved in α-decay is

$$^{248}_{96}\text{Cm} \rightarrow {}^{244}_{94}\text{Pu} + {}^{4}_{2}\text{He}.$$

Mass defect, Δm = mass of $^{248}_{96}$Cm – mass of $^{244}_{94}$Pu – mass of $^{4}_{2}$He

$= (248.072220 - 244.064100 - 4.002603)$ u

$= 0.005517$ u.

∴ the energy released in α-decay will be

$$E_\alpha = \Delta m \cdot c^2 = (0.005517 \times 931)\ \text{MeV} = 5.136\ \text{MeV}.$$

Also, $E_{\text{fission}} = 200$ MeV (given).

By question, mean life, $\tau = 10^{13}\ \text{s} = \dfrac{1}{\lambda}\cdot$

∴ disintegration constant, $\lambda = 10^{-13}\ \text{s}^{-1}$.

The rate of decay at the moment when the number of nuclei is 10^{20} is given by

$$-\frac{dN}{dt} = \lambda N = (10^{-13}\ \text{s}^{-1})\,(10^{20}) = 10^{7}\ \text{Bq}.$$

In the above disintegration, 8% is by fission and 92% is by α-decay.

Therefore, the total energy released per unit time equals

$$(8\% \times 10^{7} \times 200 + 92\% \times 10^{7} \times 5.136)\ \text{MeV s}^{-1}$$

$$= (0.08 \times 10^{7} \times 200 + 0.92 \times 10^{7} \times 5.136)\ \text{MeV s}^{-1}$$

$$= 2.074 \times 10^{8}\ \text{MeV s}^{-1} = 2.074 \times 10^{14}\ \text{eV s}^{-1} \approx 2.074 \times 1.6 \times 10^{-5}\ \text{J s}^{-1}.$$

Power output $= 2.074 \times 1.6 \times 10^{-5}$ W

$= 33.2 \times 10^{-6}\ \text{W} = 33.2\ \mu\text{W}.$

43. Energy for an H atom, $E_n = -\dfrac{13.6}{n^2} Z^2$ eV.

For transition from $2n$ to 1,

$$204 = 13.6Z^2\left[\frac{1}{1^2} - \frac{1}{(2n)^2}\right]. \qquad \dots (1)$$

For transition from $2n$ to n,

$$40.8 = 13.6Z^2\left(\frac{1}{n^2} - \frac{1}{(2n)^2}\right). \qquad \dots (2)$$

From equation (2) we get $2n = Z$. ... (3)

From equation (1) and (3) we get $Z = 4$ and $n = 2$.

$\therefore \quad 2n = 2 \times 2 = 4.$

The minimum energy for transition from 4 to 3 is

$$E = 13.6\, 4^2\left(\frac{1}{3^2} - \frac{1}{4^2}\right) \text{ eV} = 13.6 \times 4^2\left(\frac{7}{9 \times 16}\right) \text{ eV} = 10.45 \text{ eV}.$$

44. Equivalent weight of $KMnO_4$ in acidic medium $= \dfrac{M}{5} = \dfrac{158}{5} = 31.6$

(since $MnO_4^- + 8H^+ + 5e \rightarrow Mn^{2+} + 4H_2O$).

$\therefore \quad$ normality of $KMnO_4 = \dfrac{1.185}{500 \times 10^{-3}} \div 31.6$

$$= \frac{2.37}{31.6} = 0.075.$$

Using milliequivalent concept,

milliequivalent of $KMnO_4$ = milliequivalent of Fe_2O_3

or $$0.075V = \frac{0.5 \times 36\%}{80} \times 10^3 \text{ mL}$$

or $$0.075V = \frac{0.5 \times 36}{80 \times 100} \times 10^3 \text{ mL}$$

or $$V = 30 \text{ mL}.$$

$\therefore \quad$ volume of $KMnO_4$ = 30 mL.

❑

2

Practice Worksheet—2

• Type 1 •

Choose the correct option. Only one option is correct.

1. For the gas-phase reaction $2N_2O_5 \rightarrow 4NO_2 + O_2$, the rate constant k is $1.8 \times 10^{-5}\ s^{-1}$ at 25°C. The observed rate law is $r = k[N_2O_5]$. Calculate the rate for this reaction in a 12-dm^3 container with $p_{N_2O_5} = 0.10$ atm at 25°C.

(a) -1.4×10^{-7} mol dm^{-3} s^{-1} (b) 7.2×10^{-7} mol dm^{-3} s^{-1}

(c) 8.5×10^{-8} mol dm^{-3} s^{-1} (d) 7.2×10^{-8} mol dm^{-3} s^{-1}

2. In gas-phase kinetics, pressures instead of concentrations are sometimes used in rate laws. Suppose that for aA $\rightarrow$ products, one finds that $-\frac{1}{a}\frac{dp_A}{dt} = k_P p_A^n$, where k_P is a constant and p_A is the partial pressure of A. The value of k_P is

(a) $k(RT)^{1-n}$ (b) $k(RT)^{n-1}$

(c) $k(RT)^{a-n}$ (d) $k(RT)^{n-a}$

3. If $E_a = 30$ kcal mol^{-1}, a 10°C rise in temperature above the room temperature (298 K) causes the rate constant to be

(a) tripled (b) quadrupled

(c) quintupled (d) halved

4. For reactions 1 and 2, $A_1 = 5A_2$ and $k_1 = 100k_2$ at room temperature. Then the difference in energy of activation $(E_{a1} - E_{a2})$ is

(a) -1.8 kcal mol^{-1} (b) 1.8 kcal mol^{-1}

(c) -3.8 kcal mol^{-1} (d) -2.8 kcal mol^{-1}

5. Ordinary hydrogen at room temperature is a mixture of

(a) 25% orthohydrogen + 75% parahydrogen

(b) 75% orthohydrogen + 25% parahydrogen

(c) 50% orthohydrogen + 50% parahydrogen
(d) 60% orthohydrogen + 40% parahydrogen

6. Which of the following solutions has the same value of pH as 0.15-M $CH_3CO_2NH_4$?

(a) 0.10-M NH_3 (b) 0.05-M $CH_3CO_2NH_4$
(c) 0.50-M NH_3 (d) 0.15-M Na_2CO_3

7. In the van der Waals equation of state,

$$\left(p + \frac{an^2}{V^2}\right)(V - nb) = nRT,$$

(a) nV represents the total effective volume of n moles of the gas
(b) a represents the magnitude of repulsive forces
(c) the greater the value of b, the smaller is the size of the molecules
(d) the greater the value of a, the greater will be the chance of liquefaction of gases

8. The ratio of the inversion temperature of a gas to its Boyle temperature (both in kelvins) is

(a) 2.5 (b) 1.5 (c) 3.5 (d) 2.0

9.
$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(l);\ \Delta H^\circ_{298\text{ K}} = -1170 \text{ kJ mol}^{-1}$$
$$2NO(g) + O_2(g) \rightarrow 2NO_2(g);\ \Delta H^\circ_{298\text{ K}} = -114 \text{ kJ mol}^{-1}$$
$$3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(l) + NO(g);\ \Delta H^\circ_{298\text{ K}} = -72 \text{ kJ mol}^{-1}$$

Given the above $\Delta H^\circ_{298\text{K}}$ values, find $\Delta H^\circ_{298\text{K}}$ for the reaction

$$NH_3(g) + 2O_2(g) \rightarrow HNO_3(l) + H_2O(l).$$

(a) -141 kJ mol^{-1} (b) -828 kJ mol^{-1}
(c) -414 kJ mol^{-1} (d) -207 kJ mol^{-1}

10. Which of the following constants has the same unit as that of entropy?

(a) Rate constant (b) Boltzmann constant
(c) Equilibrium constant (d) Avogadro constant

11. Given that the standard reduction potentials of metallic cations $E^\circ_{A^{2+}/A} = +0.34$ V, $E^\circ_{B^{2+}/B} = -2.37$ V and $E^\circ_{C^+/C} = -3.05$ V, the order of reducing power of the corresponding metals is

(a) A > B > C (b) C > A > B (c) B > A > C (d) C > B > A

12. The order of basicity of amines

$$NH_3 < (CH_3)_3N < CH_3CH_2NH_2 < CH_3NHC_2H_5$$

is not governed by which of the following factors?

(a) Inductive effect (b) Solvation
(c) Steric effect (d) Dissociation

13. Which of the following pairs of structures are identical?

(a) Borazine and cyclohexane (b) Diborane and ethane
(c) Boron nitride and graphite (d) $B(OH)_3$ and $Al(OH)_3$

14. The decreasing order of acid strength of acetic acid, trimethylacetic acid, trichloroacetic acid and nitroacetic acid is

(a) $(CH_3)_3CCO_2H > CH_3CO_2H > CCl_3CO_2H > O_2NCH_2CO_2H$

(b) $CH_3CO_2H > (CH_3)_3CCO_2H > O_2NCH_2CO_2H > CCl_3CO_2H$

(c) $O_2NCH_2CO_2H > (CH_3)_3CCO_2H > CH_3CO_2H > CCl_3CO_2H$

(d) $CCl_3CO_2H > O_2NCH_2CO_2H > CH_3CO_2H > (CH_3)_3CCO_2H$

15. Which of the following sets of reactants are not used to prepare diborane?

(a) $Mg_3N_2 + H_3PO_4$ (b) $BF_3 + H_2$

(c) $(C_2H_5)_2O{\cdot}BF_3 + LiAlH_4$ (d) $Na[BH_4] + I_2$ + ether

16. Which of the following has the highest value of dipole moment?

(a) CH_3OH (b) CH_3NH_2

(c) CH_3NO_2 (d) CH_3Cl

17. The buffer capacity of a solution containing a weak acid and a salt of its conjugate base is maximum when

(a) [salt] = [base] (b) [salt] < [acid]

(c) [salt] > [acid] (d) $pH = pK_a$

18. Which of the following compounds is called the 'inorganic benzene'?

(a) $B_6N_6H_3$ (b) $B_3N_3H_6$

(c) $B_3N_3H_3$ (d) $B_3N_6H_6$

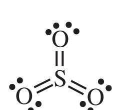
19. Consider the hypothetical reversible reaction

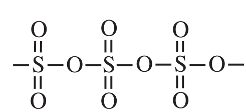
$$\frac{1}{2}A_2(g) + \frac{3}{2}B_2(g) \rightleftharpoons AB_3(g);\ \Delta H = -30\ \text{kJ mol}^{-1}.$$

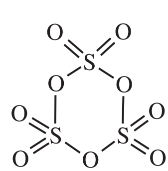
If the standard entropies of A_2, B_2 and AB_3 are 80 J K^{-1} mol^{-1}, 60 J K^{-1} mol^{-1} and 90 J K^{-1} mol^{-1} respectively, the above reaction will be at equilibrium at

(a) 450 K (b) 750 K (c) 250 K (d) 1500 K

20. Which of the following structures of sulphur trioxide is tetrahedral in shape?

(a) 

(b) 

(c) 

(d) None of these

21. Indicate which of the following species is the most stable.

(a) $CH_3\underset{+}{\overset{\overset{\displaystyle CH_3}{|}}{C}}CH_3$ (b) $CH_3\overset{+}{C}HCH_2CH_3$

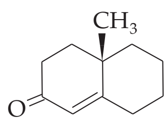
(c) $CH_2=CHOH$ (d) $CH_3CH_2CH_2CH_2\dot{C}H_2$

22. Which of the following compounds have no chirality centres?

(a) 2,3-dichloropentane

(b) 2,3-dichloro-2,3-dimethylbutane

(c) 2,3-dibromopentane

(d) 

23. Which of the following pairs is not a pair of keto-enol tautomers?

(a) $CH_3CH_2CH=CHOH$ and $CH_3CH_2CH_2\overset{\overset{\displaystyle O}{\|}}{C}H$

(b) $CH_3CH_2COCO_2C_2H_5$ and $CH_3CH=\overset{\overset{\displaystyle OH}{|}}{C}CO_2C_2H_5$

(c) $CH_3CH_2CH_2\underset{\underset{\displaystyle OH}{|}}{C}=CH_2$ and $CH_3CH_2CH_2\overset{\overset{\displaystyle O}{\|}}{C}CH_3$

(d) $CH_3CH_2CH_2CH=CHOH$ and $CH_3CH_2CH_2\overset{\overset{\displaystyle O}{\|}}{C}CH_3$

• *Type 2* •

Choose the correct option. More than one option is correct.

24. The chemical process in the production of metal using self-reduction of the oxide and the sulphide is applied for the ore

(a) galena (b) chalcopyrite

(c) haematite (d) cassiterite

25. D-Glucose and D-mannose are

(a) annomers (b) epimers

(c) diastereomers (d) oligosaccharides

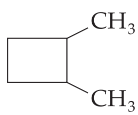
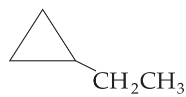
26. ClO_2 is a free radical with one unpaired electron. It has less tendency to dimerize than

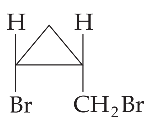
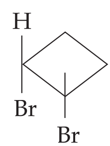
(a) NO_2 (b) ClO_3 (d) NO (d) $AlCl_3$

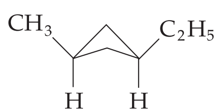
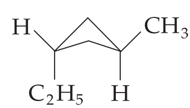
27. The N_2O_3 molecule

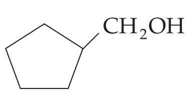
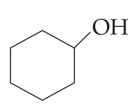
(a) has an $O_2N—NO$ structure in gas phase at low temperature
(b) has an $O_2N—NO$ structure in liquid phase at low temperature
(c) has a very long N—N bond distance
(d) dissociates easily

28. Which of the following pairs of molecules are those of constitutional isomers?

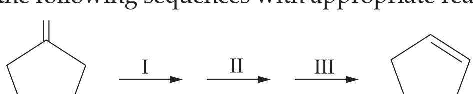
(a)  and 

(b)  and 

(c)  and 

(d)  and 

29. Complete the following sequences with appropriate reagents:



(a) I is $O_3/Zn, H_2O$; II is SeO_2; III is $OH^-/heat$
(b) I is H_2O; II is $LiAlH_4$; III is O_5O_4
(c) I is $O_3/Zn, H_2O$
(d) II is $LiAlH_4$; III is $H^+/heat$

30. A solution of $Na_2S_2O_3$ is standardized iodometrically against 0.1262 g of pure $KBrO_3$, requiring 45 mL of the $Na_2S_2O_3$ solution. What is the strength of the $Na_2S_2O_3$ solution?

(a) 0.2 M (b) 0.1 M
(c) 0.05 M (d) 0.1 N

31. In the lead storage cell,

(a) Pb is oxidized to $PbSO_4$ at the anode

(b) PbO_2 is reduced to $PbSO_4$ at the cathode

(c) both the electrodes are immersed in the same aqueous solution of H_2SO_4

(d) the use of salt bridge is not necessary

• *Comprehension-Type Questions* •

• A colourless solid (A) on strong heating gives a brown gas (B) and a grey residue (C). On dissolution of solid (A) in NH_3, a solution of compound (D) is formed. (D) oxidizes glucose. $FeSO_4$ reduces the solution of (A) in water. The aqueous solution of (A) also gives a brick-red precipitate (E) with a K_2CrO_4 solution.

32. The compound (A) will be

(a) $Pb(NO_3)_2$ (b) $AgNO_3$ (c) $Hg_2(NO_3)_2$ (d) $Bi(NO_3)_3$

33. The brown gas (B) is

(a) NO (b) N_2O_3 (c) N_2O_5 (d) NO_2

34. The grey residue (C) contains

(a) Hg (b) Bi (c) Ag (d) Pb

35. The solution (D) is

(a) BiI_3 (b) $[Ag(NH_3)_2]^+$

(c) $[Pb(NH_3)_2]^{2+}$ (d) $[HgI_4]^{2-}$

36. The brick-red precipitate (E) is

(a) Ag_2CrO_4 (b) $HgI_2 + Hg\ CrO_4$

(c) $Bi_2(CrO_4)_3$ (d) $PbCrO_4$

• *Matching-Type Questions* •

Column A	*Column B*
37. $CrO_4^{2-} \rightarrow CrO_5$	(a) PbO_2/H^+
38. $NaNO_3 \rightarrow NH_3$	(b) $H^+(aq)$
39. $Mn^{2+} \rightarrow MnO_4^-$	(c) H_2O
40. $Al(OH)_4^- \rightarrow Al(OH)_3$	(d) H_2O_2/H^+
41. $XeF_4 \rightarrow XeO_3$	(e) Devarda's alloy/OH^-

• Numerical Problems •

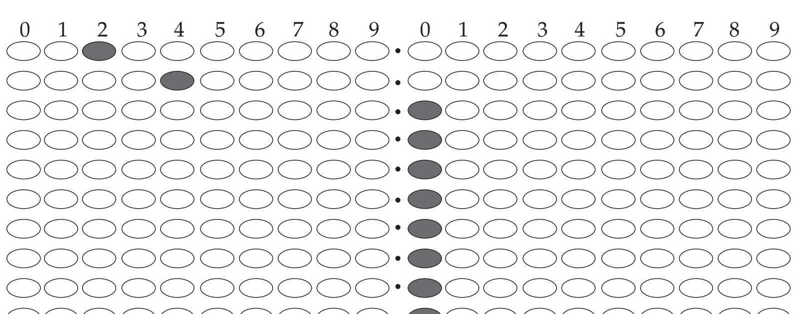
42. The molar enthalpy of fusion of anthracene is $\Delta_{fus}H_m = 28.8$ kJ mol^{-1} and its melting point is 217°C. Calculate the ideal solubility of anthracene per kilogram of benzene at 25°C.

43. For the reaction $A + 2B \rightarrow 3C + D$, the rate constant ($k$) is 2×10^{-3} L^2 mol^{-2} s^{-1} at 500 K. Introducing a catalyst at 1200 K, the rate increases to 2.71 times. Find the final activation energy if the initial activation energy is same as that of the reaction $2A \rightarrow P$, whose rate constant at 300 K in the presence of the catalyst is 2×10^{-3} min^{-1} and temperature coefficient is 2.0.

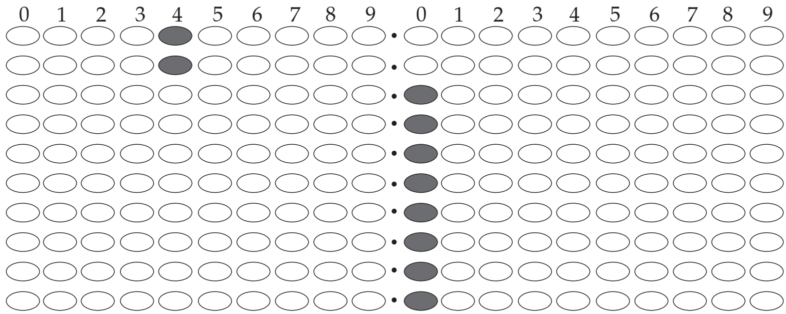
44. Ice crystallizes as a hexagonal lattice. At low temperatures the lattice parameters are found to be $a = 4.53$ Å and $c = 7.41$ Å. How many H_2O molecules are there in a unit cell (given that $P_{ice} = 0.92$ g cm^{-3} at 0°C)?

Answers

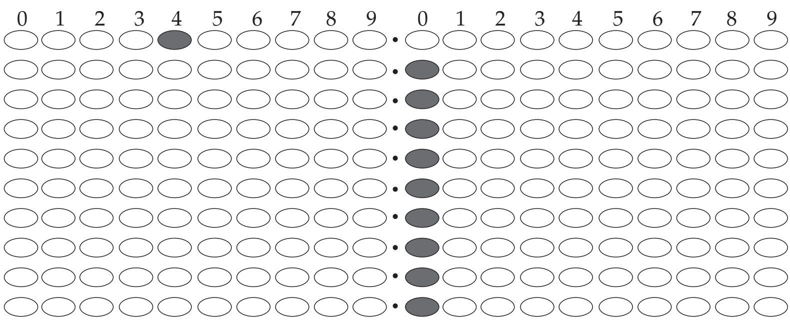
1. d	**2.** d	**3.** c	**4.** a	**5.** c
6. b	**7.** d	**8.** d	**9.** c	**10.** b
11. d	**12.** d	**13.** c	**14.** d	**15.** b
16. c	**17.** d	**18.** b	**19.** b	**20.** b
21. a	**22.** b	**23.** d	**24.** a, b	**25.** b, c
26. a, b, c, d	**27.** a, c, d	**28.** b, d	**29.** c, d	**30.** b, d
31. a, b, c				
32. b	**33.** d	**34.** c	**35.** b	**36.** a
37. ↔ d	**38.** ↔ e	**39.** ↔ a	**40.** ↔ b	**41.** ↔ c
42. 24				



43. 44



44. 4



Hints to More-Difficult Numerical Problems

42. The solubility of anthracene per kilogram of benzene can be obtained from its mole fraction with the use of equation.

$$\ln x = \frac{\Delta_{\text{fus}}H_{\text{m}}}{R}\left(\frac{1}{T^*} - \frac{1}{T}\right)$$

$$= \frac{28.8 \times 10^3 \text{ J mol}^{-1}}{8.314 \text{ J K}^{-1} \text{ mol}^{-1}}\left(-\frac{1}{490.15 \text{ K}} - \frac{1}{298.15 \text{ K}}\right)$$

$$= -4.55$$

$$x_{\text{B}} = e^{-4.55} = 0.0106.$$

Since $x_{\text{B}} < 1$, $x_{\text{B}}(\text{anthracene}) = \dfrac{n(\text{anthracene})}{n(\text{benzene})}$

or $\quad x_{\text{B}} = \dfrac{\text{mol. wt of benzene}}{1000} \times \text{molality } (m)$

(the relation between mole fraction and molality) or $x_B = \frac{78}{1000} \cdot m$ or $0.0106 = \frac{78}{1000} \cdot m$

or $m = 0.136 \text{ mol kg}^{-1}$

$\therefore$ the solubility of anthracene per kilogram of benzene is

$$(0.136 \times 178) \text{ g} \approx 24 \text{ g}.$$

43. At 500 K, $k = 2 \times 10^{-3} \text{ L}^2 \text{ mol}^{-2} \text{ s}^{-1}$ (given).

$$\ln \frac{k_2}{k_1} = \ln 2.71 \approx \ln e = 1 = \frac{E_{a1} - E_{a2}}{RT} \quad \text{or} \quad E_{a1} - E_{a2} = RT. \qquad \dots (1)$$

Again, temperature coefficient, $K_{t+10\text{ K}} = 2.0 \Rightarrow \frac{K_{310\text{ K}}}{K_{300\text{ K}}} = 2.0$

or $\ln 2.0 = \frac{E_a}{R}\left(\frac{1}{300} - \frac{1}{310}\right) = \frac{E_a}{R} \cdot \frac{1}{300 \times 31}$

or $2.303 \log 2.0 = \frac{E_a}{R} \times \frac{1}{9300}$ or $\frac{E_a}{R} = 6445.$

Here, $E_a = E_{a1}$ or $E_{a1} = 6445\, R.$ $\dots (2)$

From equations (1) and (2),

$$E_{a2} = E_{a1} - RT = (6445 \text{ K})R - RT = R(6445 \text{ K} - T)$$

$$= 8.314 \text{ J K}^{-1} \text{ mol}^{-1} \cdot (6445 - 1200) \text{ K} \qquad (\because \text{ here } T = 1200 \text{ K}).$$

$\therefore$ $E_a = 43.606 \text{ kJ mol}^{-1} \approx 44 \text{ kJ mol}^{-1}.$

44. For the hcp structure,

$$a = b \neq c, \quad \alpha = \beta = 90° \quad \text{and} \quad \gamma = 120°.$$

As we know,

$$V = abc(1 - \cos^2\alpha - \cos^2\beta - \cos^2\gamma + 2\cos\alpha \cdot \cos\beta \cdot \cos\gamma)^{1/2}$$

$$= a^2c(1 - \cos^2\gamma)^{1/2} = a^2c \cdot \sin\gamma$$

$$= (4.53 \text{ Å})^2(7.41 \text{ Å}) \sin 60° = 132 \times 10^{-24} \text{ cm}^3.$$

Mass of a unit cell $= V \times$ density

$$= (132 \times 10^{-24} \text{ cm}^3)(0.92 \text{ g cm}^{-3})(6.02 \times 10^{23} \text{ u g}^{-1})$$

$$= 73 \text{ u}.$$

This value is about four times the molecular weight of H_2O. Therefore, we conclude that there are 4 molecules of H_2O per unit cell.

❑

3

Practice Worksheet—3

• Type 1 •

Choose the correct option. Only one option is correct.

1. In which of the following cases is the principle of solubility product violated?
  (a) Addition of Na_2SO_4 to a $BaSO_4$ solution
  (b) Addition of NaBr to an AgBr solution
  (c) Addition of NaOH to an $Mg(OH)_2$ solution
  (d) Addition of KCN to an AgCN solution

2. The experimental density of a solid crystal is found to be less than the calculated density. This indicates the presence of
  (a) external impurities   (b) a line defect
  (c) a Frenkel defect   (d) a Schottky defect

3. The radius ratio (r_+/r_-) of an ionic crystal is 0.98. The crystal will have a lattice like that of
  (a) graphite   (b) TiO_2 (c) CsCl   (d) NH_4Cl

4. The abnormal behaviour of colligative properties arises due to
  (a) association of solute particles in the solvent
  (b) lower enthalpy of dilution
  (c) higher enthalpy of hydration
  (d) lowering of the vapour pressure of the solution

5. An electron in an excited state of the hydrogen atom is in the sixth energy level. When it comes back to the ground state,
  (a) energy is absorbed continuously
  (b) two spectral lines are found in the infrared region
  (c) four spectral lines are found in the visible region
  (d) six spectral lines are found in the ultraviolet region

6. The degree of hydrolysis of ammonium cyanide with a molarity of 0.2 mol L^{-1} is 0.1. Hence, the degree of hydrolysis of a 0.4-M solution of the salt will be

(a) 0.05 (b) 0.07 (c) 0.10 (d) 0.20

7. The magnetic moments of the ions $[Fe(CN)_6]^{3-}$ and $[FeF_6]^{3-}$, in Bohr magnetons, are respectively

(a) 1.73 and 2.83 (b) 1.73 and 4.90
(c) 1.73 and 1.73 (d) 1.73 and 5.92

8. The degree of dissociation of an acetic acid solution may be increased by

(a) adding H_2SO_4 to the solution
(b) adding potassium acetate to the solution
(c) increasing the temperature of acetic acid
(d) diluting the solution

9. A 0.1-molal aqueous solution of a weak acid (HX) is 10% ionized. The freezing point of the solution is (given that $K_f = 1.86$ K kg mol^{-1})

(a) −0.15°C (b) −2.0°C (c) −0.40°C (d) −0.20°C

10. Which of the following gases gets heated due to the Joule–Thomson effect at ordinary temperatures?

(a) Ammonia (b) Nitrogen
(c) Carbon dioxide (d) Hydrogen

11. Which of the following has been arranged in the increasing order of second ionization energy?

(a) N < C < Be < O (b) O < Be < N < C
(c) N < O < C < Be (d) Be < C < N < O

12. The following cell is set up at 25°C:

$$Ag(s) \mid Ag^+ \mid Cl^- \mid AgCl(s) \mid Ag(s).$$

Given that $E^\circ_{Ag^+/Ag} = 0.799$ V and $E^\circ_{AgCl/Ag(s)+Cl^-} = 0.222$ V, the solubility product of AgCl is

(a) 1.8×10^{10} (mol L^{-1})^2 (b) 1.8×10^{-10} (mol L^{-1})^2
(c) 1.8×10^{-13} (mol L^{-1})^2 (d) 1.8×10^{-17} (mol L^{-1})^2

13. Which of the following complexes has a square-planar geometry?

(a) $[Ni(CN)_4]^{2-}$ (b) $[Ni(CO)_4]$ (c) $[CoCl_4]^{2-}$ (d) $[Cu(Cl)_4]^{2+}$

14. Which of the following is a reversible half-cell electrode?

(a) $Ag \mid AgCl(s), Cl^-(aq) \parallel Cl^-, Hg_2Cl_2(s) \mid Hg$

(b) $Pt \mid MnO_4^-, Mn^{2+}, H^+ \parallel OH^-, H_2(g, 1\text{ atm}) \mid Pt$

(c) $Pt \mid Cl_2(g), Cl^- \parallel H^+, H_2(g, 1\text{ atm}) \mid Pt$

(d) $Ag \mid AgCl(s) \mid Cl^-(aq)$

15. Which of the following statements is correct?

(a) BH_3 is a poor electron acceptor compared to $B(CH_3)_3$.

(b) The trend in electron affinity for group 15 (VA) is opposite to that for group 16 (VIA).

(c) Carbon and arsenic show a diagonal relationship.

(d) On being heated, lithium hydride gives Li_2 and H_2.

16. During the rusting of iron,

(a) iron becomes a positive ion (Fe^{2+}) and forms the cathode, and the noble metal which is present as an impurity in the iron serves as the anode

(b) iron and the noble metal present in iron form an electrochemical cell on the surface of iron

(c) Fe^{II} is reduced to Fe^{I}

(d) none of these happens

17. Which of the following statements is valid in the context of the brown-ring test for nitrates?

(a) The complex forming the brown ring is $[Fe(H_2O)_5NO_3]SO_4$.

(b) The brown colour of the ring is not due to d–d transition.

(c) The oxidation state of iron in the brown ring is +III.

(d) In the iron complex which forms the brown ring, iron has three unpaired electrons.

18. When H_2SO_4 is added to a dark-red compound, the resultant solution is red in colour. When NaOH is added to this solution, the colour turns orange. Identify the compound.

(a) Pb_3O_4 (b) HgI_2 (c) Cu_2O (d) CrO_3

19. Which of the following reagents is used to distinguish Fe^{3+} from Fe^{2+}?

(a) $K_3[Fe(CN)_6]$ (b) KSCN

(c) $Fe_4[Fe(CN)_6]_3$ (d) Dimethylglyoxime

20. Sodium nitroprusside reacts with sulphide ion to give a purple complex represented by the formula

(a) $Na_2[Fe(CN)_5NOS_2]$ (b) $Na_2[Fe(CN)_4CNS]$

(c) $[Fe(CN)_5NOS]^{4-}$ (d) $[Fe(CN)_4NOS]^{3-}$

21. The chemical process in the production of copper from chalcopyrites involves

(a) reduction of the oxide

(b) oxidation of the sulphide

(c) self-reduction of the oxide and the sulphide

(d) partial oxidation of Cu_2S and FeS

22. Oxygen is heated at constant pressure through 2°C. The percentage of the heat energy supplied, which is used in increasing internal energy, is

(a) 60 (b) 71 (c) 85 (d) 40

23. Which of the following statements is correct?

(a) A compound with three chiral centres can have a maximum of nine stereoisomers.

(b) In the most stable conformation of *cis*-1-ethyl-2-methylcyclohexane, both substituents are in the equatorial position.

(c) 2,3-Dichloropentane has a stereoisomer that is a *meso* compound.

(d) 1-Butyne is more acidic than 1-butene.

24. The molecule having the highest dipole moment is

(a) CH_3F (b) CH_3Cl (c) CH_3Br (d) CH_3I

• *Type 2* •

Choose the correct options. More than one option is correct.

25. Which of the following can liberate CO_2?

(a) Phenol (b) $C_6H_5SO_3H$

(c) Cyclohexanol (d) 2,4,6-Trinitrophenol

26. Acetaldehyde responds positively to

(a) the iodoform test (b) Benedict's test

(c) the Lucas test (d) the Tollens test

27. A reagent is added to a solution of a manganous salt in hot concentrated HNO_3. A purple colour appears due to the formation of $HMnO_4$. The reagent may be

(a) $Na_2C_2O_4$ (b) $(NH_4)_2S_2O_8$

(c) $NaBiO_3$ (d) Pb_3O_4

28. The dicyanoaurate ion, $[Au(CN)_2]^-$, is readily formed by dissolving Au in a cyanide solution in the presence of

(a) air (b) H_2O_2

(c) I^- (d) SCN^-

29. Calcium cyanamide is prepared by the following reaction:

$$CaC_2(s) + N_2(g) \xrightarrow{1100°C} CaNCN(s) + C(s).$$

The NCN^{2-} ion of CaNCN is

(a) linear

(b) bent

(c) isostructural and isoelectronic with CO_2

(d) isostructural and isoelectronic with N_2O

30. During the electrolysis of an aqueous $Zn(NO_3)_2$ solution using platinum electrodes, we observe that

(a) Zn is deposited at the cathode

(b) N_2 is evolved at the anode

(c) H_2 and N_2 are evolved at the anode

(d) O_2 is evolved at the anode

31. In the Langmuir adsorption isotherm, the extent of adsorption (θ) is given by

$$\theta = \frac{bp}{1 + bp}.$$

On the basis of this equation, which of the following are correct statements?

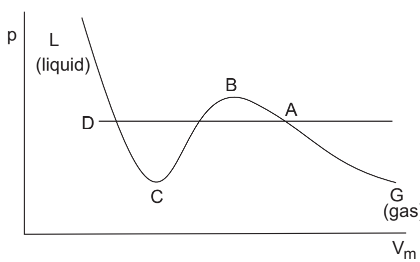
(a) When the gas is slightly adsorbed, θ will follow zero-order kinetics.

(b) When the gas is slightly adsorbed, θ will follow first-order kinetics.

(c) When the gas is strongly adsorbed, θ will follow first-order kinetics.

(d) When the gas is strongly adsorbed, θ will follow zero-order kinetics.

32.



In the above p–V_m graph,

(a) the segment AB is a metastable region corresponding to the superheated vapour

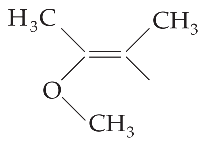
(b) the segment CD is a region of supercooled liquid

(c) at BC, $\left.\frac{\partial p}{\partial V_m}\right]_T < 0$

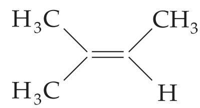
(d) at BC, $\left.\frac{\partial p}{\partial V_m}\right]_T > 0$

• *Comprehension-Type Questions* •

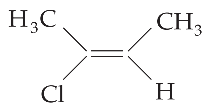
• Alkenes are characterized by C=C bonds. As such, they are subjected to electrophilic addition reactions. Examples of alkenes are shown below.



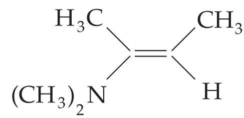
I



II



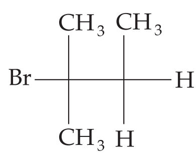
III



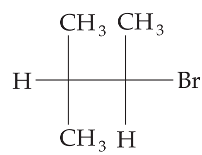
IV

33. When HBr adds to the compound II above, the main product is

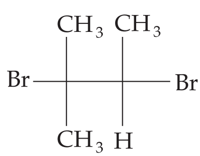
(a)



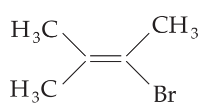
(b)



(c)



(d)

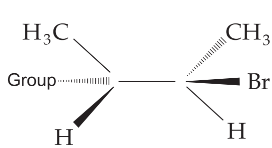


34. What is the order of reactivity of the given compounds during the electrophilic addition of HBr?

(a) II > IV > I > III (b) III > I > IV > II

(c) I > II > III > IV (d) IV > I > II > III

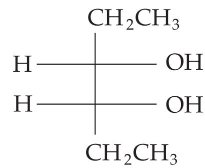
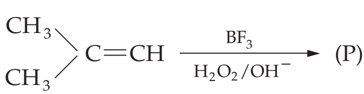
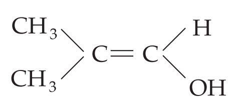
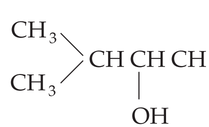
35. Which of the four compounds is most likely to form an addition product with the general structure shown below?



(a) I (b) II

(c) III (d) IV

• *Matching-Type Questions* •

Column A	**Column B**
36. $CH_3CH_2C{\equiv}CH \xrightarrow[\text{(ii) } H_2O_2/NaOH]{\text{(i) } Sia_2BH/THF} (P)$	(a) 
37. $CH_3C{\equiv}C\cdot CH_3 \xrightarrow[\text{(ii) } CH_3COOH]{\text{(i) } BF_3/THF} (P)$	(b) 
38. $CH_3CH_2C{\equiv}CH \xrightarrow[H_2SO_4(aq)]{HgSO_4} (P)$	(c) $CH_3CH_2C{\equiv}C\cdot CH_2OH$
39. $CH_3CH_2C{\equiv}CH \xrightarrow[\text{(ii) } H_3O^+]{\text{(i) } CH_3MgBr/HCHO} (P)$	(d) $CH_3CH_2CH_22CHO$
40. $CH_3CH_2C{\equiv}CH \xrightarrow[\text{(ii) } H_2/Pd/BaSO_4/KMnO_4]{\text{(i) } NaNH_2/CH_3CH_2Br} (P)$	(e) $CH_3CH_2COCH_3$
41. 	(f) $CH_3CH{\equiv}CH\cdot CH_3$
	(g) 
	(h) $CH_3CH_2CH_2CH_2CH_2CHO$
	(i) 

• *Numerical Problems* •

42. Two moles of an ideal monatomic gas occupy a volume V at 57°C. The gas expands adiabatically to a volume $2V$. Calculate the work done (in joules) by the gas during this process.

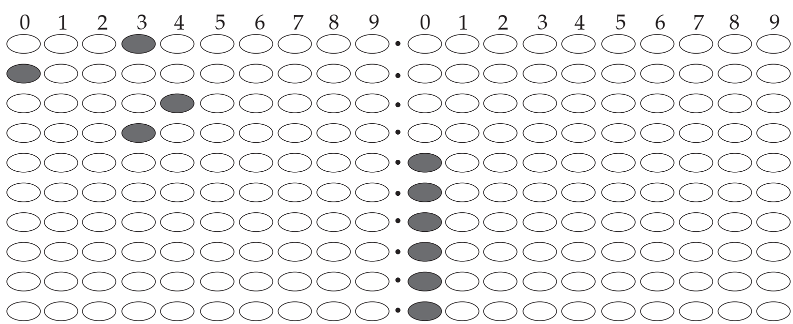
43. Two glass bulbs of equal volume are connected by a narrow tube and are filled with a gas kept at a temperature of 0°C and a pressure of 76 cmHg. One of the bulbs is then placed in melting ice and the other is placed in a water bath maintained at 62°C. Calculate the new pressure (in atm) inside the bulbs. The volume of the connecting tube is negligible.

44. Estimate the standard reduction potential (in volts) of a CuS(s) | Cu(s) electrode, given that K_s for CuS(s) is 8.5×10^{-36} (mol $L^{-1})^2$ and $E^\circ_{Cu^{2+}|Cu(s)} = +0.34$ V. Finally, calculate E° of the cell when it is coupled with an Fe^{2+} | Fe electrode, given that $E^\circ_{Fe^{2+}|Fe} = -0.45$ V.

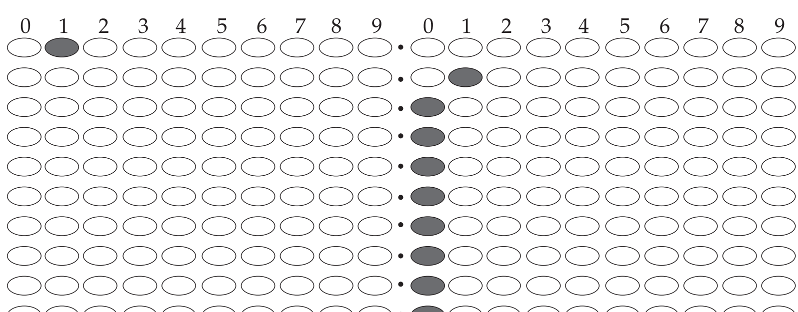
Answers

1. d	**2.** d	**3.** c	**4.** a	**5.** c
6. b	**7.** d	**8.** d	**9.** a	**10.** d
11. d	**12.** b	**13.** a	**14.** d	**15.** b
16. b	**17.** d	**18.** d	**19.** b	**20.** c
21. c	**22.** b	**23.** d	**24.** b	**25.** b, d
26. a, b, d	**27.** c, d	**28.** a, b	**29.** a, c, d	**30.** a, d
31. b, d	**32.** a, b, c			
33. a	**34.** d	**35.** c		
36. ↔ d	**37.** ↔ f	**38.** ↔ e	**39.** ↔ c	**40.** ↔ b
41. ↔ a				

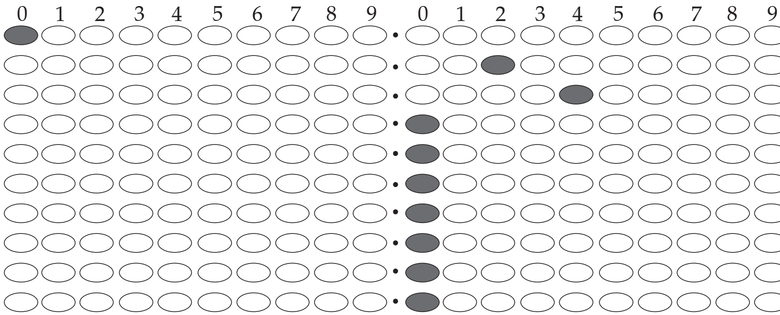
42. 3043



43. 1.1



44. 0.24



Hints to More-Difficult Numerical Problems

42. $\gamma = \frac{5}{3}$ (for monatomic gas)

$T_1 = (273 + 57)\ \text{K} = 330\ \text{K}$

$V_1 = V$

$V_2 = 2V$

$T_2 = ?$

Since the gas expands adiabatically,

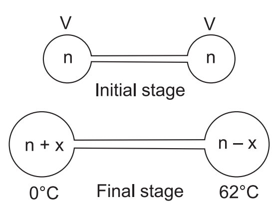
$$T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$$

or $$T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1} = (330\ \text{K})\left(\frac{V}{2V}\right)^{5/3-1} = \frac{330}{\frac{2}{3}}\ \text{K} = 208\ \text{K}.$$

$$\text{Work done} = -\frac{nR(T_2 - T_1)}{\gamma - 1} = -\frac{2 \times 8.314(208 - 330)}{\frac{5}{3} - 1}\ \text{J}$$

$$= \frac{2 \times 8.314 \times 122 \times 3}{2}\ \text{J} = 3043\ \text{J}.$$

43. Let x mol shift from the high-temperature side to the low-temperature side.



For the left bulb, $pV = nRT$.

Initially, $76\ \text{cmHg} \times V = nR \times 273\ \text{K}$.

Finally, $p' \times V = (n + x)R \times 273\ \text{K}$.

Dividing, we get $$\frac{p'}{76\ \text{cmHg}} = \frac{n + x}{n} \qquad \dots (1)$$

For the right bulb, $pV = nRT$.

Initially, $76\ \text{cmHg} \times V = nR \times 273\ \text{K}$.

Finally, $p' \times V = (n - x)R \times (273 + 62)\ \text{K}$.

Dividing, $$\frac{p'}{76 \text{ cmHg}} = \frac{n-x}{x} \times \frac{335 \text{ K}}{273 \text{ K}}. \qquad \ldots (2)$$

From (1) and (2),

$$\frac{n+x}{n} = \frac{n-x}{n} \times \frac{335 \text{ K}}{273 \text{ K}} \quad \text{or} \quad n = \frac{608}{62}x. \qquad \ldots (3)$$

Substituting (3) in (1), we get

$$\frac{p'}{76 \text{ cmHg}} = 1 + \frac{62}{608}$$

or $p' = \frac{670}{608} \times 76 \text{ cmHg} = 83.75 \text{ cmHg} = 84 \text{ cmHg} = 1.1 \text{ atm}.$

44. Let $E°$ for $CuS(s) + 2e \rightleftharpoons Cu(s) + S^{2-}$ be x.

The cell reaction is

$$Cu(s) \rightarrow Cu^{2+} + 2e; E° = 0.34 \text{ V}$$

$$\underline{CuS(s) + 2e \rightarrow Cu(s) + S^{2-}; E° = x}$$

$$CuS(s) \rightarrow Cu^{2+} + S^{2-}; E°_{cell} = x - 0.34 \text{ V}$$

We know, $\log K_s = \frac{nE°_{cell}}{0.0592}$ or $E°_{cell} = \frac{0.0592}{2}\log(8.5 \times 10^{-36}) \text{ V}$

or $x - 0.34 \text{ V} = 0.0296 \log(8.5 \times 10^{-36}) \text{ V}.$

$\therefore$ $x = -0.69 \text{ V}.$

Finally, $E° = E_{Fe^{2+}|Fe} - E°_{CuS|Cu} = -0.45 \text{ V} - (-0.69 \text{ V}) = +0.24 \text{ V}.$

❑

4

IIT Questions—1

Useful data

Molar gas constant, $R = 0.082$ L atm K^{-1} mol^{-1} = 8.314 J K^{-1} mol^{-1}

Atomic numbers: Be = 4; B = 5; C = 6; N = 7; O = 8; S = 16; Xe = 54

Atomic masses: H = 1.008; O = 16.00; S = 32.07; Se = 78.96; Te = 127.6

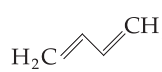
1. The rate of physisorption increases with

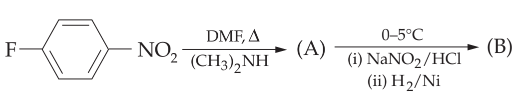
(a) decrease in temperature (b) increase in temperature

(c) decrease in pressure (d) decrease in surface area

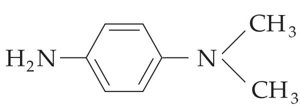
2. Which of the following represents the sp^2, sp^2, sp modes of hybridization respectively from left to right?

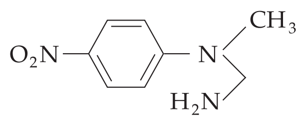
(a) $H_2C{=}CH{-}C{\equiv}N$ (b) $HC{\equiv}C{-}C{\equiv}CH$

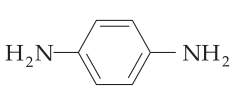
(c) $H_2C{=}C{=}C{=}CH_2$ (d) 

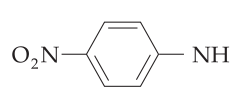
3. 

In the above reaction, the product (B) is

(a) 

(b) 

(c) 

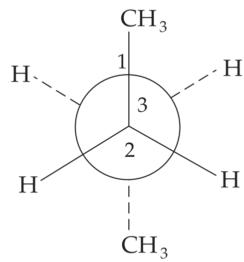
(d) 

4. 2-Phenylpropene on acidic hydration gives

(a) 2-phenyl-2-propanol (b) 2-phenyl-1-propanol

(c) 3-phenyl-1-propanol (d) 1-phenyl-2-propanol

5.



$\overset{2}{C}$ is rotated anticlockwise 120° about the $\overset{2}{C}—\overset{3}{C}$ bond. The resulting conformer is

(a) partially eclipsed (b) eclipsed
(c) gauche (d) staggered

6. If the bond length of the C—O bond in carbon monoxide is 1.128 Å then what is the value of the C—O bond length in $Fe(CO)_5$?

(a) 1.15 Å (b) 1.128 Å
(c) 1.72 Å (d) 1.118 Å

7. The species present in the solution when CO_2 is dissolved in water are

(a) CO_2, H_2CO_3, HCO_3^-, CO_3^{2-} (b) H_2CO_3, CO_3^{2-}
(c) CO_3^{2-}, HCO_3^- (d) CO_2, H_2CO_3

8. The number of P—O—P bonds in cyclic metaphosphoric acid is

(a) zero (b) two
(c) three (d) four

9. $\Delta_{vap}H_m = 30\ kJ\ mol^{-1}$ and $\Delta_{vap}S_m = 75\ J\ K^{-1}\ mol^{-1}$. Find the temperature of vapour at 1 atm.

(a) 400 K (b) 350 K
(c) 298 K (d) 250 K

10. 2 mol of an ideal gas expands isothermally and reversibly from 1 L to 10 L at 300 K. What is the enthalpy change?

(a) 4.98 kJ (b) 11.47 kJ (c) –11.47 kJ (d) 0 kJ

11. (A) follows the first-order reaction (A) $\longrightarrow$ (B). The concentration of (A) changes from 0.1 mol L^{-1} to 0.025 mol L^{-1} in 40 min. Find the rate of reaction of (A) when the concentration of (A) is 0.01 mol L^{-1}.

(a) $3.47 \times 10^{-4}\ mol\ L^{-1}\ min^{-1}$ (b) $3.47 \times 10^{-5}\ mol\ L^{-1}\ min^{-1}$
(c) $1.73 \times 10^{-4}\ mol\ L^{-1}\ min^{-1}$ (d) $1.73 \times 10^{-5}\ mol\ L^{-1}\ min^{-1}$

12. 75.2 g of C_6H_5OH (phenol) is dissolved in a solvent of $K_f = 14\ K\ kg\ mol^{-1}$. If the depression of freezing point is 7 K then find the percentage of phenol that dimerizes.

(a) 85 (b) 75 (c) 80 (d) 70

13. For the reaction $2CO + O_2 \rightarrow 2CO_2$, $\Delta H = -560$ kJ. Two moles of CO and one mole of O_2 are taken in a container of volume 1 L. They completely form two moles of CO_2. The gases deviate appreciably from their ideal behaviour. If the pressure in the vessel changes from 70 atm to 40 atm, find the magnitude (absolute value) of ΔU at 500 K, given that 1 L atm = 0.1 kJ.

(a) 583 kJ (b) 568 kJ

(c) 563 kJ (d) 583 kJ

14. We have taken a saturated solution of AgBr. K_s of AgBr is 12×10^{-14} $(\text{mol L}^{-1})^2$. If 10^{-7} mol of $AgNO_3$ is added to 1 L of this solution, find the conductivity (specific conductance) of this solution in terms of 10^{-7} S m^{-1}, given that $\lambda^\circ_{Ag^+} = 6 \times 10^{-3}$ S m^2 mol^{-1}, $\lambda^\circ_{Br^-} = 8 \times 10^{-3}$ S m^2 mol^{-1}, $\lambda^\circ_{NO_3^-} = 7 \times 10^{-3}$ S m^2 mol^{-1}.

(a) 55 (b) 65 (c) 458 (d) 75

15. The edge length of a unit cell of a metal having a molecular weight of 75 g mol^{-1} is 5 Å which crystallizes in a cubic lattice. If the density is 2 g cm^{-3} then find the radius of the metal atom (given that $N_A = 6 \times 10^{23}$ mol^{-1}).

(a) 218.5 pm (b) 210.5 pm

(c) 200.5 pm (d) 216.5 pm

16. Positive deviation from the ideal behaviour takes place because of the

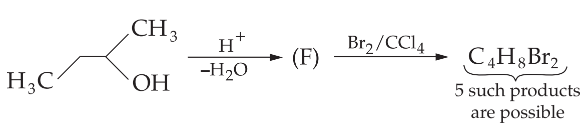
(a) molecular interaction between atoms and since $\dfrac{pV}{nRT} > 1$

(b) molecular interaction between atoms and since $\dfrac{pV}{nRT} < 1$

(c) finite size of atoms and since $\dfrac{pV}{nRT} > 1$

(d) finite size of atoms and since $\dfrac{pV}{nRT} < 1$

17.



How many structures of (F) are possible?

(a) 2 (b) 5 (c) 6 (d) 3

18. An enantiomerically pure acid is treated with a racemic mixture of an alcohol having one chiral carbon. The ester formed will be

(a) an optically active mixture (b) a pure enantiomer

(c) a *meso* compound (d) a racemic mixture

19. Lyophilic sols are

(a) irreversible sols

(b) prepared from inorganic compounds

(c) coagulated by adding electrolytes

(d) self-stabilizing

20. Which of the following resonating structures of the compound 1-methoxy-1,3-butadiene is the least stable?

(a) $\overset{\ominus}{C}H_2CH{=}CH{-}CH{=}\overset{\oplus}{O}{-}CH_3$

(b) $CH_2{=}CH{-}\overset{\ominus}{C}H{=}\overset{\oplus}{O}{-}CH_3$

(c) $\overset{\ominus}{C}H_2{-}\overset{\oplus}{C}H{-}CH{=}CH{-}O{-}CH_3$

(d) $CH_2{=}CH{-}\overset{\ominus\oplus}{C}H{-}CH{-}O{-}CH_3$

21. Match the extraction processes listed in column A with the metals listed in column B.

Column A	*Column B*
(i) Self-reduction	(a) Lead
(ii) Carbon reduction	(b) Silver
(iii) Complex formation and displacement by the metal	(c) Copper
(iv) Decomposition of the iodide	(d) Boron

22. Among the following, identify the species with an atom in its +VI oxidation state.

(a) MnO_4^- (b) $Cr(CN)_6^{3-}$

(c) NiF_6^{2-} (d) CrO_2Cl_2

23. Polyphosphates are used as water-softening agents because they

(a) form soluble complexes with anionic species

(b) precipitate anionic species

(c) form soluble complexes with cationic species

(d) precipitate cationic species

24. Identify the correct order of acidic strength of CO_2, CuO, CaO and H_2O.

(a) $CaO < CuO < H_2O < CO_2$ (b) $H_2O < CuO < CaO < CO_2$

(c) $CaO < H_2O < CuO < CO_2$ (d) $H_2O < CO_2 < CaO < CuO$

25. Identify the least stable ion amongst the following.

(a) Li^- (b) Be^-

(c) B^- (d) C^-

Consider the following equations and answer the questions below (26–28).

$$NiCl_2 + KCN\,(\text{excess}) \rightarrow (A)\ (\text{a cyano complex})$$
$$NiCl_2 + \text{conc. } HCl\,(\text{excess}) \rightarrow (B)\ (\text{a chloro complex})$$

26. The IUPAC names for (A) and (B) are respectively
- (a) Potassium tetracyanonickelate(II) and potassium tetrachloronickelate(II)
- (b) Tetracyanopotassium nickelate(II) and teterachloropotassium nickelate(II)
- (c) Tetracyanonickel(II) and tetrachloronickel(II)
- (d) Potassium tetracyanonickel(II) and potassium tetrachloronickel(II)

27. Predict the magnetic natures of (A) and (B).
- (a) Both are diamagnetic.
- (b) (A) is diamagntic and (B) is paramagnetic with one unpaired electron.
- (c) (A) is diamagnetic and (B) is paramagnetic with two unpaired electrons.
- (d) Both are paramagnetic.

28. The hybridization modes of (A) and (B) are respectively
- (a) dsp^2 and sp^3
- (b) sp^2 and sp^3
- (c) dsp^2 and dsp^2
- (d) sp^3d^3 and d^2sp^3

29. At constant temperature, the equilibrium constant K_p for the decomposition reaction $N_2O_4 \rightleftharpoons 2NO_2$ is expressed by $K_p = \dfrac{4x^2p}{1-x^2}$, where p = pressure and x = extent of decomposition. Which one of the following statements is true?
- (a) K_p increases with increase in p.
- (b) K_p increases with increase in x.
- (c) K_p increases with decrease in x.
- (d) K_p remains constant with change in p and x.

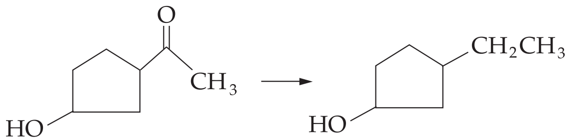
30. In an electrolytic cell, flow of electrons is from
- (a) cathode to anode in solution
- (b) cathode to anode through external supply
- (c) cathode to anode through internal supply
- (d) anode to cathode through internal supply

31. In a first-order reaction, the concentration of the reactants decreases from 800 mol dm^{-3} to 50 mol dm^{-3} in 2×10^4 s. The rate constant for the reaction is

(a) $2 \times 10^4\ s^{-1}$ (b) $3.45 \times 10^{-5}\ s^{-1}$

(c) $1.386 \times 10^{-4}\ s^{-1}$ (d) $2 \times 10^{-4}\ s^{-1}$

32.



The appropriate reagent required for the above transformation is

(a) Zn/Hg/HCl (b) NH_2NH_2/OH^-

(c) H_2/Ni (d) $NaBH_4$

33. $$N_2 + 3H_2 \rightleftharpoons 2NH_3.$$

Which is the correct statement if N_2 is added to the above system at the equilibrium condition?

(a) The equilibrium will shift to the forward direction because, according to the second law of thermodynamics, the entropy must increase in the direction of the spontaneous reaction.

(b) The condition for equilibrium is $G_{N_2} + 3G_{H_2} = 2G_{NH_3}$, where G represents the Gibbs free energy per mole of the gaseous species measured at that partial pressure. The equilibrium condition is unaffected by the use of a catalyst, as it increases the rates of both the forward and backward reactions to the same extent.

(c) The catalyst will increase the rate of the forward reaction by α and that of the backward reaction by β.

(d) The catalyst will not alter the rate of either of the reactions.

34. The reaction of propene with HOCl proceeds via the addition of

(a) H^+ in the first step (b) Cl^+ in the first step

(c) OH^- in the first step (d) Cl^+ and OH^- in a single step

The questions below (35–39) consist of an assertion in column A and reason in column B. Use the following key to choose the appropriate answer.

(a) if both assertion and reason are correct and the reason is the correct explanation of the assertion

(b) if both assertion and reason are correct but the reason is not the correct explanation of the assertion

(c) if the assertion is correct but the reason is incorrect

(d) if the assertion is incorrect but the reason is correct

Column A (assertion)	*Column B (reason)*
35. In any ionic solid [MX] with Schottky defects, the numbers of positive and negative ions are same.	The numbers of cation and anion vacancies are equal.
36. Addition of bromine to *trans*-2-butene yields *meso*-2,3-dibromobutane.	Bromine addition to an alkene is an electrophilic addition.
37. Between $SiCl_4$ and CCl_4, only $SiCl_4$ reacts with water.	$SiCl_4$ is ionic and CCl_4 is covalent.
38. Dimethyl sulphide is commonly used for the reduction of an ozonide of an alkene to get the carbonyl compounds.	It reduces the ozonide, giving water-soluble dimethyl sulphoxide, and excess of it evaporates.
39. In strongly acidic solutions, aniline becomes more reactive towards electrophilic reagents.	The amino group being completely protonated in strongly acidic solutions, the lone pair of electrons on the nitrogen atom is no longer available for resonance.

40. The order of reactivity of the following alkyl halides for an S_N2 reaction is

(a) RF > RCl > RBr > RI (b) RF > RBr > RCl > RI

(c) RCl > RBr > RF > RI (d) RI > RBr > RCl > RF

41. For the reversible reaction $N_2(g) + 3H_2(g) = 2NH_3(g)$ at 500°C, the value of K_p is 1.44×10^{-5} when partial pressure is measured in atmospheres. The corresponding value of K_c, with concentration expressed in mol L^{-1}, is

(a) $1.44 \times 10^{-5}/(0.082 \times 500)^{-2}$ (b) $1.44 \times 10^{-5}/(8.314 \times 773)^{-2}$

(c) $1.44 \times 10^{-5}/(0.082 \times 773)^{2}$ (d) $1.44 \times 10^{-5}/(0.082 \times 773)^{-2}$

42. The number of isomers of the compound with the molecular formula $C_2BrClFI$ is

(a) 3 (b) 4

(c) 5 (d) 6

43. The compound that will react most readily with NaOH to form methanol is

(a) $(CH_3)_4N^+I^-$ (b) CH_3OCH_3 (c) $(CH_3)_3S^+I^-$ (d) $(CH_3)_3CCl$

44. Which of the following molecular species has one or more unpaired electron(s)?

(a) N_2 (b) F_2

(c) O_2^- (d) O_2^{2-}

45. The nodal plane in the π bond of ethene is located in

(a) the molecular plane

(b) a plane parallel to the molecular plane

(c) a plane perpendicular to the molecular plane which bisects the C—C σ bond at right angle

(d) a plane perpendicular to the molecular plane which contains the C—C σ bond

46. The set representing the correct order of first ionization potential is

(a) K > Na > Li (b) Be > Mg > Ca

(c) B > C > N (d) Ge > Si > C

47. The correct order of hybridization of the central atoms in the species NH_3, $[PtCl_4]^{2-}$, PCl_5, BCl_3 is

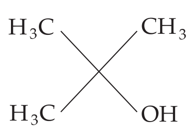
(a) dsp^2, dsp^3, sp^2, sp^3 (b) sp^3, dsp^2, dsp^3, sp^2

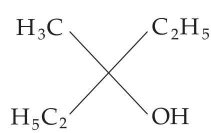
(c) dsp^2, sp^2, sp^3, dsp^3 (d) dsp^2, sp^3, sp^2, dsp^3

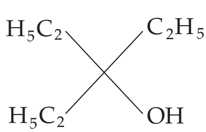
48.

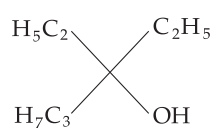
$$\text{Ethyl ester} \xrightarrow[CH_3MgBr]{\text{excess}} (P).$$

The product (P) will be

(a) 

(b) 

(c) 

(d) 

49. A mixture of 0.02 mol $[Co(NH_3)_5SO_4]Br$ and 0.02 mol $[Co(NH_3)_5Br]SO_4$ is used to prepare a solution, (X), of 2 L.

$$1\text{ L (X)} + \text{excess } AgNO_3 \rightarrow (Y)$$

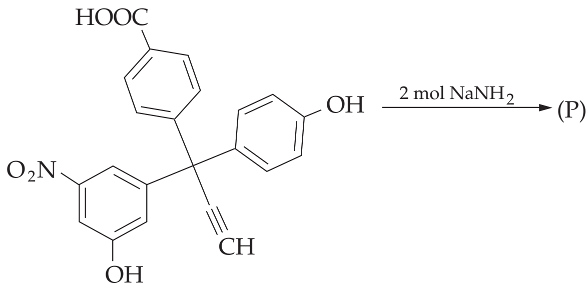
$$1\text{ L (X)} + \text{excess } BaCl_2 \rightarrow (Z).$$

The numbers of moles of (Y) and (Z) are respectively

(a) 0.01 and 0.01 (b) 0.02 and 0.01

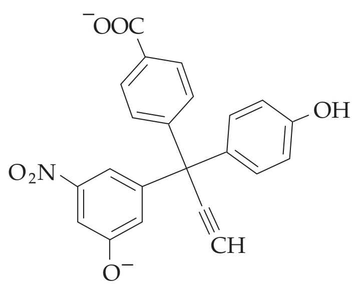
(c) 0.01 and 0.02 (d) 0.02 and 0.02

50.

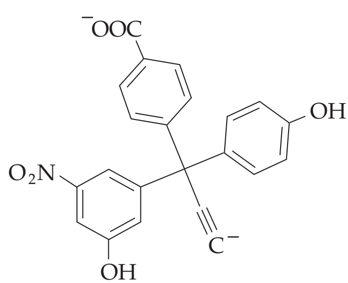


The product (P) will be

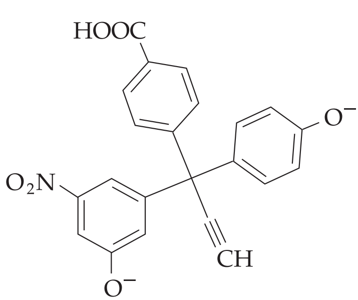
(a)

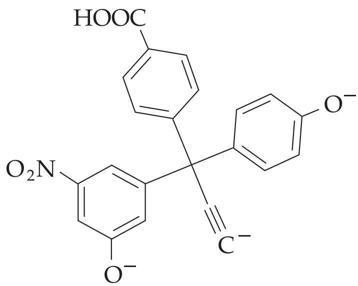


(b)



(c)



(d) 

51. HX is a weak acid ($K_a = 10^{-5}$ mol L^{-1}). It forms the salt NaX (0.1 M) on reaction with caustic soda. The degree of hydrolysis of NaX is

(a) 0.01% (b) 0.0001%

(c) 0.1% (d) 0.5%

52. Spontaneous adsorption of a gas on a solid surface is an exothermic process because

(a) ΔH increases for the system (b) ΔS increases for the gas

(c) ΔS decreases for the gas (d) ΔG increases for the gas

53. $(X) + H_2SO_4 \rightarrow (Y)$ (a colourless gas with an irritating smell)

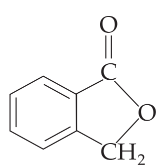
$(Y) + K_2Cr_2O_7 + H_2SO_4 \rightarrow$ a green solution.

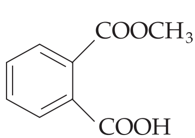
In the above equations, (X) and (Y) are respectively

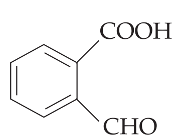
(a) SO_3^{2-} and SO_2 (b) Cl^- and HCl

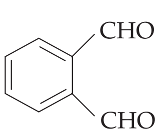
(c) S^{2-} and H_2S (d) CO_3^{2-} and CO_2

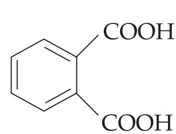
54. Which of the following reactants on reaction with concentrated NaOH followed by acidification gives the following lactone?

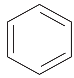


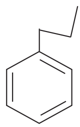
(a) 

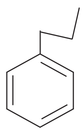
(b) 

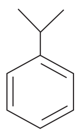
(c) 

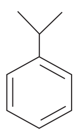
(d) 

55.  $+ Cl—CH_2CH_3—CH_2 \xrightarrow{AlCl_3} (P) \xrightarrow[\text{(ii) } H_3O^+]{\text{(i) } O_2/\Delta} (Q) + \text{phenol}$

(a)  and CH_3CH_2CHO

(b)  and CH_3COCH_3

(c)  and CH_3COCH_3

(d)  and CH_3CH_2CHO

56. Ammonia can be dried by

(a) concentrated H_2SO_4 (b) P_4O_{10}

(c) CaO (d) anhydrous $CaCl_2$

57. Specify the coordination geometry around and hybridization of the N and B atoms in a 1 : 1 complex of BF_3 and NH_3.

(a) N: tetrahedral, sp^3; B: tetrahedral, sp^3

(b) N: pyramidal, sp^3; B: pyramidal, sp^3

(c) N: pyramidal, sp^3; B: planar, sp^2

(d) N: pyramidal, sp^3; B: tetrahedral, sp^3

58. The rusting of iron takes place as follows:

$$2H^+ + 2e^- + \frac{1}{2}O_2 \longrightarrow H_2O(l);\ E° = +1.32\ V$$

$$Fe^{2+} + 2e^- \longrightarrow Fe(s);\ E° = -0.44\ V.$$

Calculate $\Delta G°$ for the net process.

(a) -322 kJ mol^{-1} (b) -161 kJ mol^{-1}

(c) -152 kJ mol^{-1} (d) -76 kJ mol^{-1}

59. The elevation of boiling point of a solution of 13.44 g $CuCl_2$ in 1 kg of water will be (given that the molecular weight of $CuCl_2$ is 134.4 and $K_b = 0.52$ K kg mol^{-1})

(a) 0.16 K (b) 0.05 K (c) 0.1 K (d) 0.2 K

60. The ratio of the rates of diffusion of helium and methane under identical conditions of pressure and temperature will be

(a) 4 (b) 2 (c) 1 (d) 0.5

61. In which of the following crystals are alternate tetrahedral voids occupied?

(a) NaCl (b) ZnS (c) CaF_2 (d) Na_2O

62. Which of the following statements is false?

(a) Work is a state function.

(b) Temperature is a state function.

(c) Change in the state is completely defined when the initial and final states are specified.

(d) Work appears at the boundary of the system.

63. Me_2SiCl_2 on hydrolysis will produce

(a) $Me_2Si(OH)_2$ (b) $Me_2Si{=}O$

(c) $—[—O—Me_2Si—O—]_n—$ (d) $Me_2SiCl(OH)$

64. A solution which is 10^{-3} M each in Mn^{2+}, Fe^{2+}, Zn^{2+} and Hg^{2+} is treated with 10^{-16} M sulphide ion. If the values of K_s for MnS, FeS, ZnS and HgS are 10^{-15} (mol L^{-1})^2, 10^{-23} (mol L^{-1})^2, 10^{-20} (mol L^{-1})^2 and 10^{-54} (mol L^{-1})^2 respectively, which one will precipitate first?

(a) FeS (b) MgS

(c) HgS (d) ZnS

65. In the process of extraction of gold,

$$\text{roasted gold ore} + CN^- + H_2O \xrightarrow{O_2} (X) + OH^-$$

$$(X) + Zn \longrightarrow (Y) + Au$$

Identify the complex ions (X) and (Y).

(a) $(X) = [Au(CN)_2]^-$ and $(Y) = [Zn(CN)_4]^{2-}$

(b) $(X) = [Au(CN)_4]^{3-}$ and $(Y) = [Zn(CN)_4]^{2-}$

(c) $(X) = [Au(CN)_2]^-$ and $(Y) = [Zn(CN)_6]^{4-}$

(d) $(X) = [Au(CN)_4]^-$ and $(Y) = [Zn(CN)_4]^{2-}$

66. The chemical process involved in the production of steel from haematite ore is

(a) reduction

(b) oxidation

(c) reduction followed by oxidation

(d) oxidation followed by reduction

67. The number of radial nodes of 3s and 2p orbitals are respectively

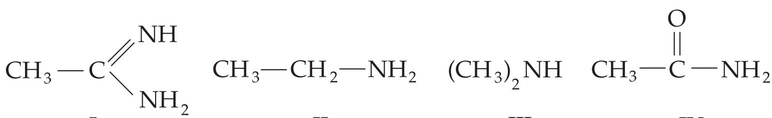
(a) 2 and 0 (b) 0 and 2

(c) 1 and 2 (d) 2 and 1

68. Which species has the maximum number of lone pairs of electrons on the central atom?

(a) $[ClO_3]^-$ (b) XeF_4 (c) SF_4 (d) I_3^-

69. Which is the correct order of basicity of the following compounds?

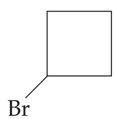
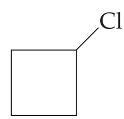


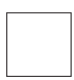
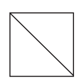
I II III IV

(a) II > I > III > IV (b) I > III > II > IV

(c) III > I > II > IV (d) I > II > III > IV

70. What would be the product formed when 1-bromo-3-chlorocyclobutane reacts with two equivalents of metallic sodium in ether?

(a)  (b) 

(c)  (d) 

71. In the standardization of $Na_2S_2O_3$ using $K_2Cr_2O_7$ by iodometry, the equivalent weight of $K_2Cr_2O_7$ is

(a) (molecular weight)/2 (b) (molecular weight)/6

(c) (molecular weight)/3 (d) same as molecular weight

72. The direct conversion of (A) to (B) is difficult, hence it is carried out by the following path.

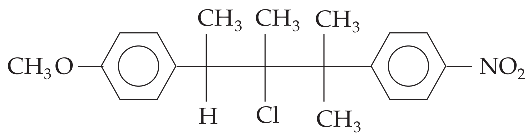
$$\begin{tikzcd} (C) \arrow[r] & (D) \arrow[d] \\ (A) \arrow[u] & (B) \end{tikzcd}$$

Given that $\Delta S_{(A) \to (C)} = 50$ e.u., $\Delta S_{(C) \to (D)} = 30$ e.u., $\Delta S_{(B) \to (D)} = 20$ e.u., e.u. being the entropy unit, the value of $\Delta S_{(A) \to (B)}$ is

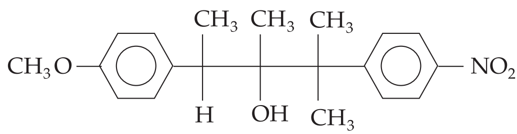
(a) +100 e.u. (b) +60 e.u.

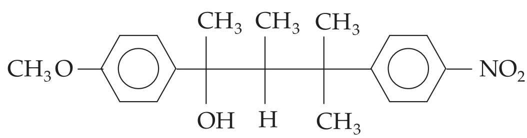
(c) –100 e.u. (d) –60 e.u.

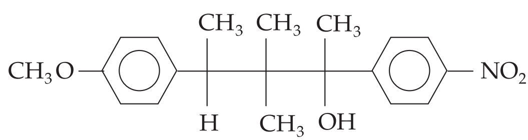
73.



Which compound(s) among the following is/are given by the above compound on hydrolyis in aqueous acetone?

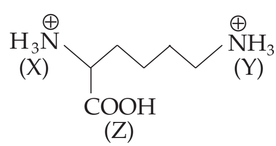
(I) 

(II) 

(III) 

(a) Mixture of I and II
(b) Mixture of I and III
(c) Only III
(d) Only I

74.



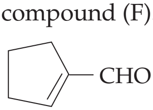
Arrange in the increasing order of acidic strength.

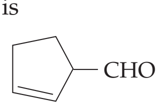
(a) (X) > (Z) > (Y)
(b) (Z) < (X) < (Y)
(c) (X) > (Y) > (Z)
(c) (Z) > (X) > (Y)

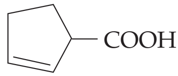
75. A 0.004-M Na_2SO_4 solution is isotonic with a 0.01-M glucose solution. The degree of dissociation of Na_2SO_4 is

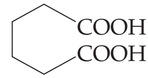
(a) 75% (b) 50% (c) 25% (d) 85%

76. Cyclohexene on ozonolysis followed by a reaction with Zn dust and water gives a compound (E). (E) on further treatment with aqueous KOH yields a compound (F). The compound (F) is

(a) 

(b) 

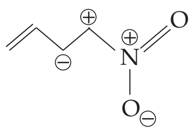
(c) 

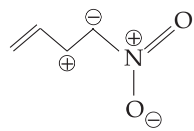
(d) 

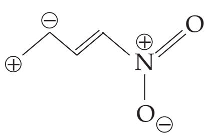
77. Among the following metal carboxyls, the C—O bond order is the lowest in

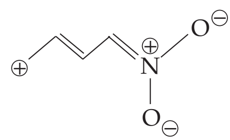
(a) $[Mn(CO)_6]^+$
(b) $[Fe(CO)_5]$
(c) $[Cr(CO)_6]$
(d) $[V(CO)_6]^-$

78. Among the following, the least stable resonance structure is

(a) 

(b) 

(c) 

(d) 

79. Consider the titration of a potassium dichromate solution with an acidified Mohr salt solution using diphenylamine as the indicator. The number of moles of the Mohr salt required per mole of the dichromate is

(a) 3
(b) 4
(c) 5
(d) 6

80. For the process

$$H_2O(l)\ (1\ \text{bar},\ 373\ \text{K}) \rightarrow H_2O(g)\ (1\ \text{bar},\ 373\ \text{K}),$$

the correct set of thermodynamic parameters is

(a) $\Delta G = 0, \Delta S > 0$
(b) $\Delta G = 0, \Delta S < 0$
(c) $\Delta G > 0, \Delta S = 0$
(d) $\Delta G < 0, \Delta S > 0$

81. A solution of a metal ion when treated with KI gives a red precipitate which dissolves in excess KI to give a colourless solution. Moreover, the solution of the metal ion on treatment with a solution of cobalt(II) thiocyanate gives rise to a deep blue crystalline precipitate. The metal ion is

(a) Pb^{2+}
(b) Hg^{2+}
(c) Cu^{2+}
(d) Co^{2+}

Answers

1. a	**2.** a	**3.** a	**4.** a	**5.** c
6. a	**7.** a	**8.** c	**9.** a	**10.** d
11. a	**12.** b	**13.** c	**14.** a	**15.** d
16. a	**17.** d	**18.** a	**19.** d	**20.** d

21. (i) $\leftrightarrow$ a , c (ii) $\leftrightarrow$ a, c (iii) $\leftrightarrow$ b (iv) $\leftrightarrow$ d

22. d	**23.** c	**24.** a	**25.** b	**26.** a
27. c	**28.** a	**29.** d	**30.** c	**31.** c
32. b	**33.** b	**34.** b	**35.** a	**36.** b
37. c	**38.** a	**39.** d	**40.** d	**41.** d
42. d	**43.** c	**44.** c	**45.** a	**46.** b
47. b	**48.** a	**49.** a	**50.** a	**51.** a
52. c	**53.** a	**54.** c	**55.** c	**56.** c
57. a	**58.** a	**59.** a	**60.** b	**61.** b
62. a	**63.** c	**64.** c	**65.** a	**66.** c
67. a	**68.** d	**69.** b	**70.** d	**71.** b
72. b	**73.** a	**74.** a	**75.** a	**76.** a
77. d	**78.** a	**79.** d	**80.** a	**81.** b

❑

5

IIT Questions—2

Useful data

Planck constant, $h = 6.626 \times 10^{-34}$ J s

Atomic numbers: Cr = 24, Mn = 25, Fe = 26, Co = 27, Pt = 78

1. For H_3PO_3 and H_3PO_4 the correct choice(s) is/are
(a) H_3PO_3 is dibasic and reducing
(b) H_3PO_4 is dibasic and nonreducing
(c) H_3PO_4 is tribasic and reducing
(d) H_3PO_3 is tribasic and nonreducing

2. When MnO_2 is fused with KOH, a coloured compound is formed. The product and its colour are respectively
(a) K_2MnO_4 and purple-green (b) $KMnO_4$ and purple
(c) Mn_2O_3 and brown (d) Mn_3O_4 and black

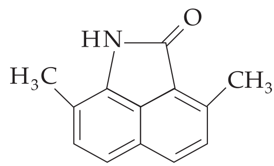
3. The name of the structure of silicates in which three oxygen atoms of $[SiO_4]^{4-}$ are shared is
(a) pyrosilicate (b) sheet silicate
(c) linear-chain silicate (d) three-dimensional silicate

4. Which is the most thermodynamically stable allotropic form of phosphorus?
(a) Red phosphorus (b) White phosphorus
(c) Black phosphorus (d) Yellow phosphorus

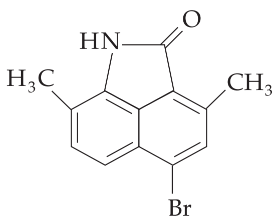
5. Which ore contains both iron and copper?
(a) Cuprite (b) Chalcocite
(c) Chalcopyrite (d) Malachite

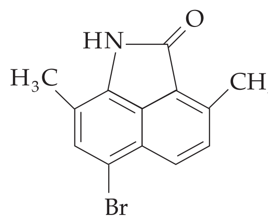
6. Which of the following is not oxidized by O_3?
(a) KI (b) $FeSO_4$ (c) $KMnO_4$ (d) K_2MnO_4

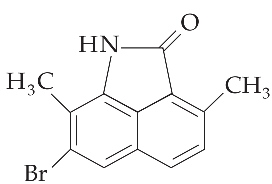
7.

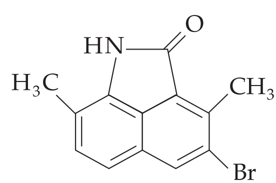


The product on monobromination of the above compound is

(a) 

(b) 

(c) 

(d) 

8. $(NH_4)_2Cr_2O_7$ on heating gives a gas which is also given by

(a) heating NH_4NO_2

(b) heating NH_4NO_3

(c) $Mg_3N_2 + H_2O$

(d) $NaNO_3 + H_2O_2$

9. Electrolytic reduction of alumina to aluminium by the Hall–Héroult process is carried out in the presence of

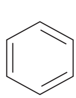
(a) NaCl

(b) fluorite

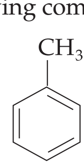
(c) cryolite, which forms a melt with a lower melting temperature

(d) cryolite, which forms a melt with a higher melting temperature

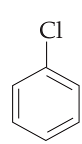
10. Identify the correct order of reactivity in electrophilic substitution reactions of the following compounds:



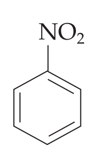
I



II



III



IV

(a) I > II > III > IV

(b) IV > III > II > I

(c) II > I > III > IV

(d) II > III > I > IV

11. Benzamide on treatment with $POCl_3$ gives

(a) aniline (b) benzonitrile
(c) chlorobenzene (d) benzylamine

12. The methods chiefly used for the extraction of lead and tin from their ores are respectively

(a) self-reduction and carbon reduction
(b) self-reduction and electrolytic reduction
(c) carbon reduction and self-reduction
(d) cyanide process and carbon reduction

13. A mixture of benzaldehyde and formaldehyde on heating with aqueous NaOH solution gives

(a) benzyl alcohol and sodium formate
(b) sodium benzoate and methyl alcohol
(c) sodium benzoate and sodium formate
(d) benzyl alcohol and methyl alcohol

14. The complex ion which has no d electrons in the central metal atom is

(a) $[MnO_4]^-$ (b) $[Co(NH_3)_6]^{3+}$
(c) $[Fe(CN)_6]^{3-}$ (d) $[Cr(H_2O)_6]^{3+}$

15. Which blue liquid is obtained on reacting equimolar amounts of two gases at –30°C?

(a) N_2O (b) N_2O_3
(c) N_2O_4 (d) N_2O_5

16. When PbO_2 reacts with concentrated HNO_3, the gas evolved is

(a) NO_2 (b) O_2 (c) N_2 (d) N_2O

17. A metal nitrate reacts with KI to give a black precipitate which on addition of excess of KI is converted into an orange solution. The cation of the metal nitrate is

(a) Hg^{2+} (b) Bi^{3+} (c) Pb^{2+} (d) Cu^+

18. The number of nodal planes in a p_x orbital is

(a) one (b) two (c) three (d) zero

19. Anhydrous ferric chloride is prepared by

(a) heating hydrated ferric chloride at a high temperature in a stream of air
(b) heating metallic iron in a stream of dry chlorine gas
(c) reaction of ferric oxide with hydrochloric acid
(d) reaction of metallic iron with hydrochloric acid

20. Identify the correct order of solubility of Na_2S, CuS and ZnS in the aqueous medium.

(a) $CuS > ZnS > Na_2S$ (b) $ZnS > Na_2S > CuS$

(c) $Na_2S > CuS > ZnS$ (d) $Na_2S > ZnS > CuS$

21. $$B(OH)_3 + NaOH \rightleftharpoons NaBO_2 + Na[B(OH)_4] + H_2O$$

How can the above reaction is made to proceed in the forward direction?

(a) Addition of *cis*-1,2-diol (b) Addition of borax

(c) Addition of *trans*-1,2 diol (d) Addition of Na_2HPO_4

The questions below (22–26) consist of an assertion in column A and reason in column B. Use the following key to choose the appropriate answer.

(a) if both assertion and reason are correct and the reason is the correct explanation of the assertion

(b) if both assertion and reason are correct but the reason is not the correct explanation of the assertion

(c) if the assertion is correct but the reason is incorrect

(d) if the assertion is incorrect but the reason is correct

Column A (assertion)	*Column B (reason)*
22. The first ionization energy of Be is greater than that of B.	The 2p orbital is lower in energy than the 2s orbital.
23. The heat absorbed during the isothermal expansion of an ideal gas against vacuum is zero.	The volume occupied by the molecules of an ideal gas is zero.
24. Phenol is more reactive than benzene towards electrophilic substitution reactions.	In the case of phenol, the intermediate carbocation is more resonance-stabilized.
25. 1-Butene on reaction with HBr in the presence of a peroxide produces 1-bromobutane.	It involves the formation of a primary radical.
26. The pressure of a fixed amount of an ideal gas is proportional to its temperature.	The frequency of collisions and their impact increase in proportion to the square root of temperature.

27. According to the MO theory,

(a) O_2^+ is paramagnetic and its bond order is greater than that of O_2

(b) O_2^+ is paramagnetic and its bond order is less than that of O_2

(c) O_2^+ is diamagnetic and its bond order is greater than that of O_2

(d) O_2^+ is diamagnetic and its bond order is less than that of O_2

Answer the questions below (28–30) using the following information.

Carbon-14 is used to determine the age of organic materials. The procedure is based on the formation of ^{14}C by neutron capture in the upper atmosphere.

$$^{14}_{7}N + ^{1}_{0}n \rightarrow ^{14}_{6}C + ^{1}_{1}n$$

^{14}C is absorbed by living organisms during photosynthesis. The ^{14}C content is constant in a living organism. Once the plant or animal dies, the uptake of carbon dioxide by it ceases and the level of ^{14}C in the dead being falls due to the decay which C^{14} undergoes.

$$^{14}_{6}C \rightarrow ^{14}_{7}N + \beta^-$$

The half-life of ^{14}C is 5770 years. The decay constant (λ) can be calculated by using the formula $\lambda = \dfrac{0.693}{t_{1/2}}$. The comparison of the β^- activity of the dead matter with that of the carbon still in circulation enables measurement of the period of the isolation of the material from the living cycle. The method, however, ceases to be accurate over periods longer than 30,000 years. The ratio of ^{14}C to ^{12}C in living matter is $1 : 10^{12}$.

28. Which of the following options is correct?

(a) In living organisms, circulation of ^{14}C from the atmosphere is high, so the carbon content is constant in an organism.

(b) Carbon dating can be used to find out the age of the earth's crust and rocks.

(c) Radioactive absorption due to cosmic radiation is equal to the rate of radioactive decay. Hence the carbon content remains constant in living organisms.

(d) Carbon dating cannot be used to determine the concentration of ^{14}C in dead beings.

29. What should be the age of a fossil for meaningful determination of its age?

(a) 6 years (b) 6000 years

(c) 60,000 years (d) Any age

30. A nuclear explosion has taken place leading to increase in the concentration of ^{14}C in nearby areas. The ^{14}C concentration is c_1 in nearby areas and c_2 in areas far away. If the age of the similar fossils is determined to be T_1 in nearby areas and T_2 in faraway areas then

(a) the age of the fossils will increase at the place where explosion has taken place and $T_1 - T_2 = \dfrac{1}{\lambda} \ln \dfrac{c_1}{c_2}$

(b) the age of the fossils will decrease at the place where explosion has taken place and $T_1 - T_2 = \dfrac{1}{\lambda} \ln \dfrac{c_1}{c_2}$

(c) the age of the fossils will be determined to be the same

(d) $\dfrac{T_1}{T_2} = \dfrac{c_1}{c_2}$

31. 2-Hexyne gives *trans*-2-hexene on treatment with

(a) Li/NH_3 (b) $Pd/BaSO_4$
(c) $LiAlH_4$ (d) Pt/H_2

32. How many chiral compounds are possible on monochlorination of 2-methylbutane?

(a) 2 (b) 4
(c) 6 (d) 8

33. Which of the following pairs gives positive Tollens test?

(a) Glucose and sucrose (b) Glucose and fructose
(c) Hexanal and acetophenone (d) Fructose and sucrose

34. Match the following:

Column A	***Column B***
(i) $CH_3—CHBr—CD_3$ on treatment with alcoholic KOH gives $CH_2=CH—CD_3$ as the major product	(a) E1 reaction
(ii) $Ph—CHBr—CH_3$ reacts faster than $Ph—CHBr—CD_3$	(b) E2 reaction
(iii) $Ph—CH_2—CH_2Br$ on treatment with C_2H_5OD/C_2H_5O gives $Ph—CD=CH_2$ as the major product	(c) E1cB reaction
(iv) $Ph—CH_2—CH_2Br$ and $Ph—CD_2—CH_2Br$ react at the same rate	(d) First-order reaction

35. For the electrochemical cell $M \mid M^+ \parallel X^- \mid X$, $E^\circ_{M^+\mid M} = 0.44$ V and $E^\circ_{X\mid X^-} = 0.33$ V. From these data, one can deduce that

(a) $M + X \rightarrow M^+ + X^-$ is the spontaneous reaction
(b) $M^+ + X^- \rightarrow M + X$ is the spontaneous reaction
(c) $E_{cell} = +0.77$ V
(d) $E_{cell} = -0.77$ V

36. One mole of a nonideal gas undergoes the change of state

$$(2.0 \text{ atm}, 3.0 \text{ L}, 95 \text{ K}) \rightarrow (4.0 \text{ atm}, 5.0 \text{ L}, 245 \text{ K})$$

with a change in internal energy, $\Delta U = 30.0$ L atm. The change in enthalpy (ΔH) of the process is

(a) 40.0 L atm
(b) 42.3 L atm
(c) 44.0 L atm
(d) not defined because pressure is not constant

37. When one mole of a monatomic ideal gas at T K undergoes adiabatic change under a constant external pressure of 1 atm, its volume changes from 1 L to 2 L. The final temperature would be

(a) $\frac{T}{2^{2/3}}$ K (b) $\left(T + \frac{2}{3} \times 0.0821\right)$ K

(c) T K (d) $\left(T - \frac{2}{3} \times 0.0821\right)$ K

38. The spin quantum numbers $+\frac{1}{2}$ and $-\frac{1}{2}$ represent respectively

(a) the rotation of the electron in clockwise and anticlockwise directions

(b) the rotation of the electron in anticlockwise and clockwise directions

(c) the magnetic moment of the electron pointing up and down

(d) two quantum-mechanical spin states which have no classical analogues

39. Which one of the following statements is not correct for order of reaction?

(a) Order can be determined experimentally.

(b) Order of reaction is equal to sum of the powers of concentration terms in differential rate law.

(c) It is not affected by the stoichiometric coefficient of the reactants.

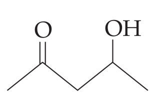
(d) Order cannot be fractional.

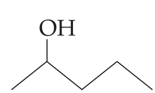
40. 0.1 mol of CH_3NH_2 ($K_b = 5 \times 10^{-4}$ mol L^{-1}) is mixed with 0.08 mol of HCl and diluted to one litre. What will be the H^+ concentration in the solution?

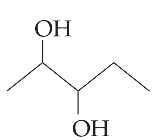
(a) 8×10^{-2} mol L^{-1} (b) 8×10^{-11} mol L^{-1}

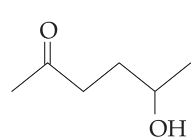
(c) $1 \cdot 6 \times 10^{-11}$ mol L^{-1} (d) 8×10^{-5} mol L^{-1}

41. Which one of the following will most readily be dehydrated in acidic condition?

(a) 

(b) 

(c) 

(d) 

42. Consider the following equilibrium in a closed container:

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

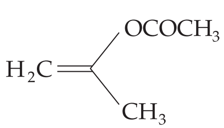
At a fixed temperature, the volume of the reaction container is halved. For this change, which of the following statements holds true regarding the equilibrium constant (K_p) and degree of dissociation (α)?

(a) Neither K_p nor α changes.
(b) Both K_p and α change.
(c) K_p changes, but α does not change.
(d) K_p does not change, but α changes.

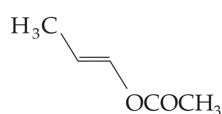
43. 1-Propanol and 2-propanol can be best distinguished by

(a) oxidation with alkaline $KMnO_4$ followed by reaction with Fehling's solution
(b) oxidation with acidic dichromate followed by reaction with Fehling's solution
(c) oxidation by heating with copper followed by reaction with Fehling's solution
(d) oxidation with concentrated H_2SO_4 followed by reaction with Fehling's solution

44.



(P)

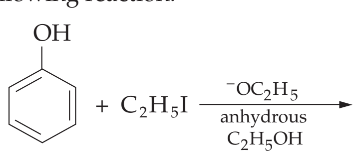


(Q)

The products of the acid hydrolysis of (P) and (Q) can be distinguished by

(a) the Lucas reagent (b) 2, 4-DNP
(c) Fehling's solution (d) $NaHSO_3$

45. Complete the following reaction:



(a) $C_6H_5—O—C_2H_5$ (b) $C_2H_5—O—C_2H_5$
(c) $C_6H_5—O—C_6H_5$ (d) C_6H_5I

46. A hydroxide which is acidic in water is

(a) $Al(OH)_3$ (b) $Be(OH)_3$ (c) $La(OH)_3$ (d) $B(OH)_3$

47. Which has the maximum number of atoms?

(a) 24 g of ^{12}C (b) 56 g of ^{56}Fe
(c) 27 g of ^{27}Al (d) 108 g of ^{108}Ag

48. Propyne and propene can be distinguished by

(a) concentrated H_2SO_4 (b) Br_2 in CCl_4
(c) dilute $KMnO_4$ (d) $AgNO_3$ in ammonia

49. In the presence of peroxide compounds, hydrogen chloride and hydrogen iodide do not give the anti-Markovnikov addition to alkenes because

(a) both are highly ionic
(b) one is oxidizing and the other is reducing
(c) one of the steps is endothermic in both the cases
(d) all the steps are exothermic in both the cases

50. If $CuSO_4$ decolorizes on addition of KCN,

(a) the product is $[Cu(CN)_4]^{2-}$
(b) Cu^{2+} gets reduced to form $[Cu(CN)_4]^{3-}$
(c) the product is $Cu(CN)_2$
(d) CuCN is produced

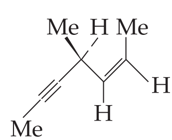
51. The wavelength associated with a golf ball weighing 200 g and moving at a speed of 5 m/h is of the order

(a) 10^{-10} m (b) 10^{-20} m (c) 10^{-30} m (d) 10^{-40} m

52. An S_N2 reaction at an asymmetric carbon of a compound always gives

(a) an enantiomer of the substrate
(b) a product with opposite optical rotation
(c) a mixture of diastereoisomers
(d) a single stereoisomer

53.



Hydrogenation of the above compound in the presence of poisoned palladium catalyst gives

(a) an optically active compound (b) an optically inactive compound
(c) a racemic mixture (d) a diastereoisomeric mixture

54. The electronic configuration of an element is $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^5\,4s^1$. This represents its

(a) excited state (b) ground state
(c) cationic form (d) anionic form

55. The rms velocity of hydrogen is $\sqrt{7}$ times the rms velocity of nitrogen. If T stands for temperature then

(a) $T_{H_2} = T_{N_2}$ (b) $T_{H_2} > T_{N_2}$ (c) $T_{H_2} < T_{N_2}$ (d) $T_{H_2} = \sqrt{7}T_{N_2}$

56. What are the common features among the species CN^-, CO and NO^+?

(a) They have the bond order 3 and are isoelectronic.

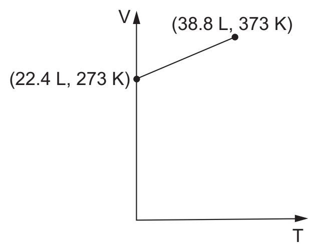
(b) They have the bond order 3 and are weak-field ligands.

(c) They are π-acceptors having the bond order 2.

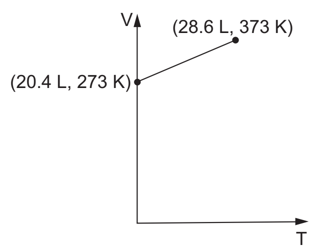
(d) They are isoelectronic and are weak-field ligands.

57. Which of the following volume–temperature (*V*–*T*) plots represents the behaviour of one mole of an ideal gas at one atmospheric pressure?

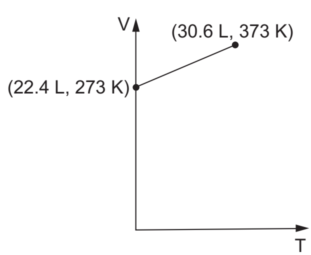
(a)



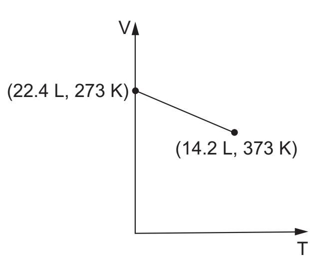
(b)



(c)



(d)



58. A substance A_xB_y crystallizes in a face-centred-cubic (fcc) lattice in which the A atoms occupy each corner of the cube and the B atoms occupy the centres of each face of the cube. Identify the correct composition of the substance A_xB_y.

(a) AB_3

(b) A_4B_3

(c) A_3B

(d) Its composition cannot be specified.

59. If the density of liquid water is 1.0 g cm^{-3} and that of water vapour is 0.0006 g cm^{-3} at 100°C and 1 atm then the volume occupied by water molecules in 1 L of steam at that temperature and pressure is

(a) 6 cm^3 (b) 60 cm^3 (c) 0.6 cm^3 (d) 0.06 cm^3

60. How many moles of electrons weigh one kilogram?

(a) 6.023×10^{23} (b) $\frac{1}{9.108} \times 10^{31}$

(c) $\frac{6.023}{9.108} \times 10^{54}$ (d) $\frac{1}{9.108 \times 6.023} \times 10^{8}$

61. The IUPAC name for C_6H_5COCl is

(a) benzoyl chloride (b) benzene chloroketone

(c) benzene carbonyl chloride (d) chlorophenyl ketone

62.
$$Ag^+ + NH_3 \rightleftharpoons [AgNH_3]^+;\ k_1 = 3.5 \times 10^{-3}$$
$$[AgNH_3]^+ + NH_3 \rightleftharpoons [Ag(NH_3)_2]^+;\ k_2 = 1.7 \times 10^{-3}$$

Then the formation constant of $[Ag(NH_3)_2]^+$ is approximately

(a) 6.0×10^{-6} (b) 6.0×10^{6}

(c) 6.0×10^{-9} (d) none of the above

63. In thermodynamics, a process is called reversible when

(a) the surroundings and the system change into each other

(b) there is no boundary between the system and the surroundings

(c) the surroundings are always in equilibrium with the system

(d) the system changes into the surroundings spontaneously

64. $CH_3NH_2 + CHCl_3 + KOH \rightarrow$ a nitrogen-containing compound $+ KCl + H_2O$. The nitrogen-containing compound is

(a) $CH_3—C{\equiv}N$ (b) $CH_3—NH—CH_3$

(c) $CH_3—\overset{-}{N}{\equiv}\overset{+}{C}$ (d) $CH_3\overset{+}{N}{\equiv}\overset{-}{C}$

65. Which of the following has the —O—O— linkage?

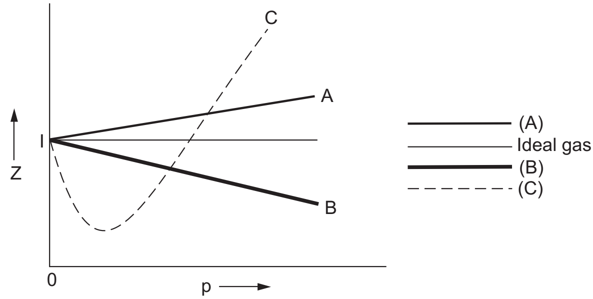
(a) $H_2S_2O_6$ (b) $H_2S_2O_8$

(c) $H_2S_2O_3$ (d) $H_2S_4O_6$

66. When I^- is oxidized by MnO_4^- in an alkaline medium, I^- converts into

(a) IO_3^- (b) I_2 (c) IO_4^- (d) IO^-

67. The following graph represents the variation of the compressibility factor, $Z = \frac{pV}{nRT}$, versus p, for three real gases (A), (B) and (C). Identify the incorrect statement.



(a) For the gas (A), $a = 0$ and its dependence on p is linear at all values of pressure.

(b) For the gas (B), $b = 0$ and its dependence on p is linear at all values of pressure.

(c) For the gas (C), neither a nor b is equal to zero. By knowing the minima and the point of intersection, with $Z = 1$, a and b can be calculated.

(d) At high pressure, the slope is positive for all real gases.

68. The rate constant for the reaction $2N_2O_5 \rightarrow 4NO_2 + O_2$ is $3.0 \times 10^{-5}\ s^{-1}$. If the rate is 2.40×10^{5} mol $L^{-1}\ s^{-1}$ then the concentration of N_2O_5 is

(a) 1.4 mol L^{-1} (b) 1.2 mol L^{-1}

(c) 0.04 mol L^{-1} (d) 0.8 mol L^{-1}

69. Standard electrode potential data are useful for understanding the suitability of an oxidant in a redox titration. Some half-cell reactions and their standard potentials are given below:

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l);\ E° = +1.51\ V$$

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l);\ E° = +1.38\ V$$

$$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq);\ E° = +0.77\ V$$

$$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq);\ E° = +1.40\ V.$$

Now identify the only incorrect statement regarding the quantitative estimation of aqueous $Fe(NO_3)_2$.

(a) MnO_4^- can be used in aqueous HCl.

(b) $Cr_2O_7^{2-}$ can be used in aqueous HCl.

(c) MnO_4^- can be used in aqueous H_2SO_4.

(d) $Cr_2O_7^{2-}$ can be used in aqueous H_2SO_4.

70. In a solid AB having the NaCl structure, A atoms occupy the corners of the cubic unit cell. If all the face-centred atoms along one of the axes are removed then the resultant stoichiometry of the solid is

(a) AB_2 (b) A_2B (c) A_4B_3 (d) A_3B_4

71. When diluted with H_2O and boiled, a solution gives a white precipitate. On addition of excess NH_4Cl/NH_4OH, the volume of the precipitate decreases leaving behind a white gelatinous precipitate. Identify the precipitate which dissolves in NH_4Cl/NH_4OH.

(a) $Zn(OH)_2$ (b) $Al(OH)_3$
(c) $Mg(OH)_2$ (d) $Ca(OH)_2$

72. When benzenesulphonic acid and *p*-nitrophenol are treated with $NaCO_3$, the gases released respectively are

(a) SO_2 and NO_2 (b) SO_2 and NO
(c) SO_2 and CO_2 (d) CO_2 and CO_2

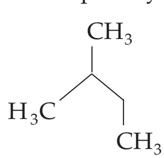
73. A monatomic ideal gas undergoes a process in which the ratio of P to V at any instant is constant and equals 1. What is the molar heat capacity of the gas?

(a) $\frac{4R}{2}$ (b) $\frac{3R}{2}$
(c) $\frac{5R}{2}$ (d) 0

74. The smallest ketone and its next homologue are reacted with NH_2OH to form oximes. Then

(a) two different oximes are formed
(b) three different oximes are formed
(c) two oximes are optically active
(d) all oximes are optically active

75.



$\xrightarrow[Cl_2]{h\nu}$ N isomeric products

$C_5H_{11}Cl \xrightarrow[\text{distillation}]{\text{fractional}}$ M isomeric products

What are the values of N and M?

(a) 6 and 6 (b) 6 and 4 (c) 4 and 4 (d) 3 and 3

76. Consider a reaction $a(G) + b(H) \rightarrow (P)$. When the concentrations of both the reactants (G) and (H) are doubled, the rate increases by eight times. However, when the concentration of (G) is doubled keeping the concentration of (H) fixed, the rate is doubled. The overall order of the reaction is

(a) 0 (b) 1 (c) 2 (d) 3

77. The number of stereoisomers obtained by the bromination of *trans*-2-butene is

(a) 1 (b) 2 (c) 3 (d) 4

78. A positron is emitted from $^{33}_{11}Na$. The ratio of the atomic mass and atomic number of the resulting nuclide is

(a) 22 : 10 (b) 22 : 11 (c) 23 : 10 (d) 23 : 12

79. A species having a bond order different from that in CO is

(a) NO^- (b) NO^+ (c) CN^- (d) N_2

80. Among the following the paramagnetic compound is

(a) Na_2O_2 (b) O_3 (c) N_2O (d) KO_2

81. The extraction of zinc from zinc blende is achieved by

(a) electrolytic reduction
(b) roasting followed by reduction with carbon
(c) roasting followed by reduction with another metal
(d) roasting followed by self-reduction

Answers

1. a, c	**2.** a	**3.** b	**4.** c	**5.** b
6. c	**7.** b	**8.** a	**9.** c	**10.** c
11. b	**12.** a	**13.** a	**14.** a	**15.** b
16. b	**17.** b	**18.** a	**19.** b	**20.** d
21. a	**22.** a	**23.** c	**24.** a	**25.** c
26. b	**27.** a	**28.** c	**29.** b	**30.** a
31. a	**32.** b	**33.** b		

34. (i) $\leftrightarrow$ b (ii) $\leftrightarrow$ b (iii) $\leftrightarrow$ c, d (iv) $\leftrightarrow$ a, d

35. b	**36.** c	**37.** a	**38.** d	**39.** d
40. b	**41.** a	**42.** d	**43.** c	**44.** c
45. b	**46.** d	**47.** a	**48.** d	**49.** c
50. d	**51.** c	**52.** d	**53.** b	**54.** b
55. c	**56.** a	**57.** c	**58.** a	**59.** c
60. d	**61.** c	**62.** a	**63.** c	**64.** d
65. b	**66.** a	**67.** b	**68.** d	**69.** a
70. d	**71.** a	**72.** d	**73.** a	**74.** b
75. b	**76.** d	**77.** a	**78.** c	**79.** a
80. d	**81.** b			

❑

6

IIT Questions—3

Useful data Mass of an electron, $m_e = 9.108 \times 10^{-31}$ kg Avogadro constant, $N_A = 6.023 \times 10^{23}$ mol^{-1} Molar gas constant, $R = 0.082$ L atm K^{-1} mol^{-1} Atomic numbers: Li = 3, Be = 4, B = 5, C = 6

1. The molecular shapes of SF_4, CF_4 and SeF_4 are

(a) similar, with 2, 0 and 1 lone pairs of electrons, respectively
(b) similar, with 1, 1 and 1 lone pairs of electrons, respectively
(c) different, with 0, 1 and 2 lone pairs of electrons, respectively
(d) different, with 1, 0 and 2 lone pairs of electrons, respectively

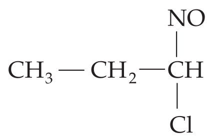
2. (I) 1,2-Dihydroxybenzene
(II) 1,3-Dihydroxybenzene
(III) 1,4-Dihydroxybenzene
(IV) Hydroxybenzene

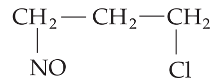
The increasing order of boiling point of the above-mentioned alcohols is

(a) I < II < III < IV (b) I < II < IV < III
(c) IV < I < II < III (d) IV < II < I < III

3.
$$CH_3—CH{=}CH_2 + NOCl \rightarrow (P)$$
Identify the adduct (P).

(a) $CH_3 — \underset{\displaystyle Cl}{\underset{|}{CH}} — \underset{\displaystyle NO}{\underset{|}{CH_2}}$ (b) $CH_3 — \underset{\displaystyle NO}{\underset{|}{CH}} — \underset{\displaystyle Cl}{\underset{|}{CH_2}}$

(c) 

(d) 

4. Among the following, which is the strongest base?

(a) $C_6H_5—NH_2$ (b) p-($NO_2—C_6H_4—NH_2$)

(c) m-($NO_2—C_6H_4—NH_2$) (d) $C_6H_5—CH_2—NH_2$

5. Which of the following compounds will exhibit geometrical isomerism?

(a) 1-Phenyl-2-butene (b) 3-Phenyl-1-butene

(c) 2-Phenyl-1-butene (d) 1,1-Diphenyl-1-propene

6. Consider the chemical reaction $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$. The rate of this reaction can be expressed in terms of the time derivative of concentration of $N_2(g)$, $H_2(g)$ or $NH_3(g)$. Identify the correct relationship amongst the following rate expressions.

(a) $\text{Rate} = -\dfrac{d[N_2]}{dt} = -\dfrac{1}{3}\cdot\dfrac{d[H_2]}{dt} = \dfrac{1}{2}\cdot\dfrac{d[NH_3]}{dt}$

(b) $\text{Rate} = -\dfrac{d[N_2]}{dt} = -3\dfrac{d[H_2]}{dt} = 2\dfrac{d[NH_3]}{dt}$

(c) $\text{Rate} = \dfrac{d[N_2]}{dt} = \dfrac{1}{3}\cdot\dfrac{d[H_2]}{dt} = \dfrac{1}{2}\cdot\dfrac{d[NH_3]}{dt}$

(d) $\text{Rate} = -\dfrac{d[N_2]}{dt} = -\dfrac{d[H_2]}{dt} = \dfrac{d[NH_3]}{dt}$

7. The set with correct order of acidity is

(a) $HClO < HClO_2 < HClO_3 < HClO_4$

(b) $HClO_4 < HClO_3 < HClO_2 < HClO$

(c) $HClO < HClO_4 < HClO_3 < HClO_2$

(d) $HClO_4 < HClO_2 < HClO_3 < HClO$

8. Among the following the molecule with the highest dipole moment is

(a) CH_3Cl (b) CH_2Cl_2

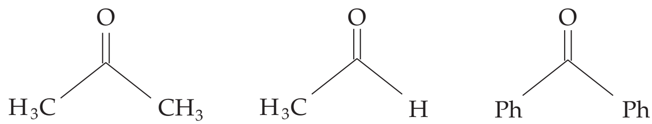
(c) $CHCl_3$ (d) CCl_4

9. Which of the following are isoelectronic as well as isostructural?

(a) NO_3^-, CO_3^{2-} (b) SO_3, NO_3^-

(c) ClO_3^-, CO_3^{2-} (d) CO_3^{2-}, SO_3

10. Find the order of reactivity of phenyl magnesium bromide with the following compounds:



I II III

(a) II > III > I (b) I > III > II

(c) II > I > III (d) I = III = II

- The Tollens reagent is used for the detection of aldehyde. When a solution of $AgNO_3$ is added to glucose with NH_4OH, gluconic acid is formed.

$$Ag^+ + e^- \rightarrow Ag;\ E^\circ_{red} = +0.8\ V$$

$$C_6H_{12}O_6 + H_2O \rightarrow C_6H_{12}O_7\ \text{(gluconic acid)} + 2H^+ + 2e^-;\ E^\circ_{ox} = -0.05\ V$$

$$Ag(NH_3)_2^+ + e^- \rightarrow Ag(s) + 2NH_3;\ E^\circ_{red} = +0.337\ V$$

Use $2.303 \times \frac{RT}{F} = 0.0592$ and $\frac{F}{RT} = 38.92$ at 298 K.

11. $$2Ag^+ + C_6H_{12}O_6 + H_2O \rightarrow 2Ag(s) + C_6H_{12}O_2 + 2H^+.$$

Find ln K for this reaction.

(a) 66.13 (b) 58.38

(c) 28.30 (d) 46.29

12. When ammonia is added to the solution, its pH is raised to 11. Which half-cell reaction is affected by pH and by how much?

(a) E_{ox} will increase by a factor of 0.65 from E°_{ox}.

(b) E_{ox} will decrease by a factor of 0.65 from E°_{ox}.

(c) E_{red} will increase by a factor of 0.65 from E°_{red}.

(d) E_{red} will decrease by a factor of 0.65 from E°_{red}.

13. Ammonia is always is added in this reaction. Which of the following must be incorrect?

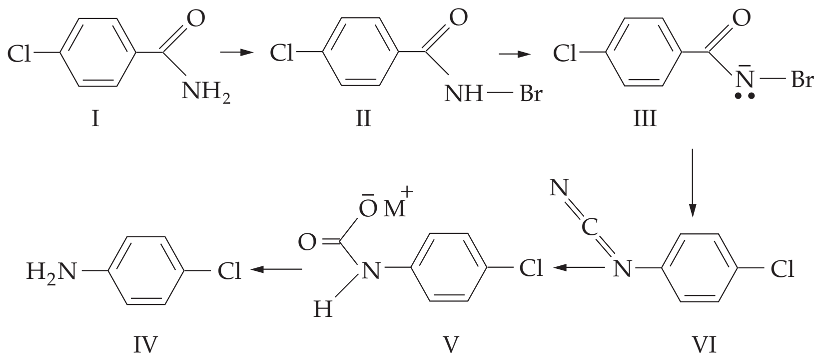
(a) NH_3 combines with Ag^+ to form a complex.

(b) $Ag(NH_3)_2^+$ is a stronger oxidizing reagent than Ag^+.

(c) In absence of NH_3, silver salt of gluconic acid is formed.

(d) NH_3 has affected the standard reduction potential of the glucose/gluconic acid electrode.

- $RCONH_2$ is converted into RNH_2 by means of the Hofmann bromamide degradation.



In this reaction, RCONHBr is formed, from which this reaction has derived its name. The electron-donating group at phenyl activates the reaction. The Hofmann degradation reaction is an intramolecular reaction.

14. What can bring about the conversion of I to II?

(a) KBr (b) KBr + CH_3ONa

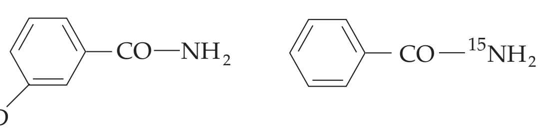
(c) KBr + KOH (d) Br_2 + KOH

15. Which is the rate-determining step in the Hofmann bromamide degradation?

(a) Formation of I (b) Formation of II

(c) Formation of III (d) Formation of IV

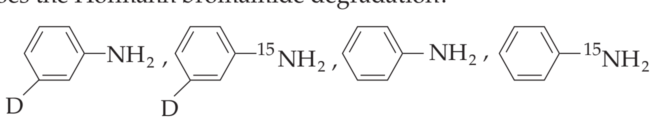
16.



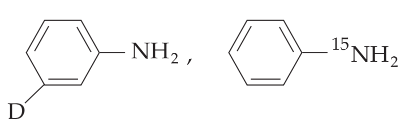
I II

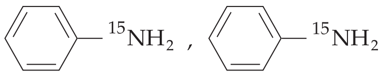
What are the constituent amines formed when the mixture of I and II undergoes the Hofmann bromamide degradation?

(a)



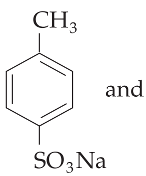
(b)

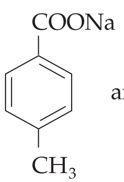


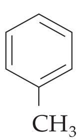
(c) 

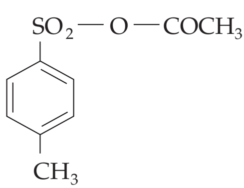
(d) 

17. 4-Methylbenzenesulphonic acid reacts with sodium acetate to give

(a)  and CH_3COOH

(b)  and SO_3

(c)  and SO_3

(d)  and SO_3

18. Match the following columns:

Column A	*Column B*
(i) $Br^{3+} \rightarrow [BiO]^+$	(a) Heat
(ii) $[AlO_2]^- \rightarrow Al(OH)_3$	(b) Hydrolysis
(iii) $[SiO_4]^{4-} \rightarrow [Si_2O_7]^{4-}$	(c) Acidification
(iv) $[B_4O_7]^{2-} \rightarrow B(OH)_3$	(d) Dilution by water

19. The best method to prepare cyclohexene from cyclohexanol is by using

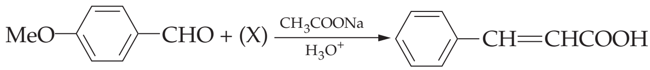
(a) concentrated HCl and $ZnCl_2$ (b) concentrated H_3PO_4

(c) HBr (d) concentrated HCl

20. What can convert butan-2-one to propanoic acid?

(a) Tollens reagent (b) Fehling's solution

(c) $NaOH/I_2/H^+$ (d) $NaOH/NaI/H^+$

21. 

The compound (X) is

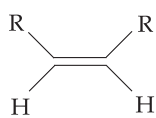
(a) CH_3COOH (b) $BrCH_2—COOH$

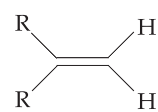
(c) $(CH_3CO)_2O$ (d) $CHO—COOH$

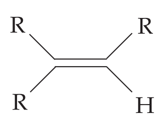
22. According to Bohr's theory, E_n = total energy, K_n = kinetic energy, V_n = potential energy and r_n = radius of the nth orbit. Now match the following columns:

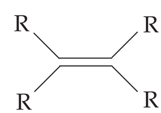
Column A	***Column B***
(i) V_n/K_n equals	(a) 0
(ii) If $r_n \propto E_n^x$ then x is	(b) –1
(iii) The angular momentum in the lowest orbital is	(c) –2
(iv) If $\frac{1}{r^n} \propto Z^y$ then y equals	(d) 1

23. Which one of the following alkenes will react fastest with H_2 under the catalytic hydrogenation condition?

(a) 

(b) 

(c) 

(d) 

24. An aqueous solution of 6.3 g oxalic acid dihydrate is made up to 250 mL. The volume of the 0.1-N NaOH solution required to completely neutralize 10 mL of this solution is

(a) 40 mL (b) 20 mL

(c) 10 mL (d) 4 mL

25. Identify from the following list the reagents which can easily distinguish between 1-butyne and 2-butyne.

(a) Bromine, CCl_4 (b) H_2, Lindlar catalyst

(c) Dilute H_2SO_4, $HgSO_4$ (d) Ammoniacal Cu_2Cl_2 solution

26. The number of electrons involved in the conversion of OH^- to O_2 is

(a) one (b) four

(c) two (d) three

27. The pair of compounds having metals in their highest oxidation states is

(a) MnO_2, $FeCl_3$ (b) $[MnO_4]^-$, CrO_2Cl_2

(c) $[Fe(CN)_6]^{3-}$, $Co(CN)_3$ (d) $[NiCl_4]^{2-}$, $[CoCl_4]^+$

28. The compound having a tetrahedral geometry is

(a) $[Ni(CN)_4]^{2-}$ (b) $[Pd(CN)_4]^{2-}$

(d) $[PdCl_4]^{2-}$ (d) $[NiCl_4]^{2-}$

29. Which hydrogen-like species has the same radius as that of the Bohr orbit of the hydrogen atom?

(a) $n = 2$, Li^{2+} (b) $n = 2$, Be^{3+}

(c) $n = 2$, He^+ (d) $n = 3$, Li^{2+}

30. The hybridization modes of atomic orbitals of nitrogen in NO_2^+, NO_3^- and NH_4^+ are respectively

(a) sp, sp^3 and sp^2 (b) sp, sp^2 and sp^3

(c) sp^2, sp and sp^3 (d) sp^2, sp^3 and sp

31. The chemical composition of the 'slag' formed during the smelting process in the extraction of copper is

(a) $Cu_2O + FeS$ (b) $FeSiO_3$ (c) $CuFeS_2$ (d) $Cu_2S + FeO$

32. Which of the following acids has the smallest dissociation constant?

(a) $CH_3CHFCOOH$ (b) FCH_2CH_2COOH

(c) $BrCH_2CH_2COOH$ (d) $CH_3CHBrCOOH$

33. Consider the following reaction:

$$H_3C-\underset{\displaystyle D}{\underset{|}{CH}}-\underset{\displaystyle CH_3}{\underset{|}{CH}}-CH_3 + \dot{Br} \longrightarrow (X) + HBr$$

Identify the structure of the major product (X).

(a) $H_3C-\underset{\displaystyle D}{\underset{|}{CH}}-\underset{\displaystyle CH_3}{\underset{|}{CH}}-\dot{C}H_2$ (b) $H_3C-\underset{\displaystyle D}{\underset{|}{CH}}-\underset{\displaystyle CH_3}{\underset{|}{\dot{C}}}-CH_2$

(c) $H_3C-\underset{\displaystyle D}{\underset{|}{\dot{C}}}-\underset{\displaystyle CH_3}{\underset{|}{CH}}-CH_3$ (d) $H_3C-\dot{C}H-\underset{\displaystyle CH_3}{\underset{|}{CH}}-CH_3$

34. The spin-only magnetic moment of the compound $Hg[Co(SCN)_4]$ is

(a) $\sqrt{3}$ (b) $\sqrt{15}$ (c) $\sqrt{24}$ (d) $\sqrt{8}$

35. A sodium salt having an unknown anion when treated with $MgCl_2$ gives a white precipitate on boiling. The anion is

(a) SO_4^{2-} (b) HCO_3^- (c) CO_3^{2-} (d) NO_3^-

36. The correct order of radius is

(a) $N < Be < B$ (b) $F^{-} < O^{2-} < N^{3-}$

(c) $Na < Li < K$ (d) $Fe^{3+} < Fe^{2+} < Fe^{4+}$

37. The ΔH_f° for $CO_2(g)$, $CO(g)$ and $H_2O(g)$ are -393.5 kJ mol^{-1}, -110.5 kJ mol^{-1} and -241.8 kJ mol^{-1} respectively. The standard enthalpy change for the reaction $CO_2(g) + H_2(g) \rightarrow CO(g) + H_2O(g)$ is

(a) 524.1 kJ (b) 41.2 kJ

(c) -262.5 kJ (d) -41.2 kJ

38. Identify the set of reagents and/or reaction conditions (X) and (Y) in the following set of transformations:

$$CH_3-CH_2-CH_2Br \xrightarrow{(X)} (P) \xrightarrow{(Y)} CH_3-\underset{\displaystyle Br}{\underset{|}{CH}}-CH$$

(a) (X) = dilute aqueous NaOH, 20°C; (Y) = HBr/acetic acid, 20°C

(b) (X) = concentrated alcoholic NaOH, 80°C; (Y) = HBr/acetic acid, 20°C

(c) (X) = dilute aqueous NaOH, 20°C; (Y) = $Br_2/CHCl_3$, 0°C

(d) (X) = concentrated alcoholic NaOH, 80°C; (Y) = $Br_2/CHCl_3$, 0°C

39. Among H_2O, H_2S, H_2Se and H_2Te, the one with the highest boiling point is

(a) H_2O because of its hydrogen bonding

(b) H_2Te because of its higher molecular weight

(c) H_2S because of its hydrogen bonding

(d) H_2Se because of its lower molecular weight

40. A compound (A) having the molecular formula C_3H_8O is treated with acidified potassium dichromate to form a product (B) having the molecular formula C_3H_6O. (B) forms a shining silver mirror on warming with ammoniacal silver nitrate. (B) when treated with an aqueous solution of $H_2NCONHNH_2\cdot HCl$ and sodium acetate gives a product (C). Identify the structure of (C).

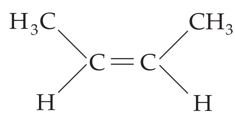
(a) $CH_3CH_2CH{=}NNHCONH_2$

(b) $CH_3-\underset{\displaystyle CH_3}{\underset{|}{C}}{=}NNHCONH_2$

(c) $CH_3-C{=}\underset{\displaystyle CH_3}{\underset{|}{N}}CONHNH_2$

(d) $CH_3CH_2CH{=}NCONHNH_2$

41. Which of the following hydrocarbons has the lowest dipole moment?

(a) 

(b) $CH_3C{=}CCH_3$

(c) $CH_3CH_2C{\equiv}CH$

(d) $CH_2{=}CH{-}C{\equiv}CH$

42. Which of the following has the highest nucleophilicity?

(a) F^- (b) OH^- (c) CH_3^- (d) NH_2^-

43. Benzoyl chloride is prepared from benzoic acid using

(a) heated Cl_2 (b) SO_2Cl_2

(c) $SOCl_2$ (d) Cl_2 and H_2O

44. The compressibility of a gas is less than unity at stp. Therefore,

(a) $V_m > 22.4\ \text{L mol}^{-1}$ (b) $V_m < 22.4\ \text{L mol}^{-1}$

(c) $V_m = 22.4\ \text{L mol}^{-1}$ (d) $V_m = 44.8\ \text{L mol}^{-1}$

45. Which of the following processes is used in the extractive metallurgy of magnesium?

(a) Fused-salt electrolysis (b) Self-reduction

(c) Aqueous-solution electrolysis (d) Thermite reduction

46. An aqueous solution of a substance gives a white precipitate on treatment with dilute hydrochloric acid, which dissolves on heating. When hydrogen sulphide is passed through the hot acidic solution, a black precipitate is obtained. The substance is a(n)

(a) Hg^{II} salt (b) Cu^{II} salt

(c) Ag^{I} salt (d) Pb^{II} salt

47. A gas (X) is passed through water to form a saturated solution. The aqueous solution on treatment with silver nitrate gives a white precipitate. The saturated aqueous solution also dissolves magnesium ribbon with evolution of a colourless gas (Y). Identify (X) and (Y).

(a) $(X) = CO_2$; $(Y) = Cl_2$ (b) $(X) = Cl_2$; $(Y) = CO_2$

(c) $(X) = Cl_2$; $(Y) = H_2$ (d) $(X) = H_2$; $(Y) = Cl_2$

48. If I is the intensity of absorbed light and c is the concentration of AB for the photochemical process $AB + h\nu \rightarrow AB^*$, the rate of formation of AB^* is directly proportional to

(a) c (b) I (c) I^2 (d) $c \cdot I$

49. The correct order of equivalent conductance of LiCl, NaCl and KCl at infinite dilution is

(a) LiCl > NaCl > KCl (b) KCl > NaCl > LiCl

(c) NaCl > KCl > LiCl (d) LiCl > KCl > NaCl

50. For a monatomic gas, kinetic energy $= E$. Its relation with rms velocity (u) is

(a) $u = \left(\frac{2E}{m}\right)^{1/2}$ (b) $u = \left(\frac{3E}{2m}\right)^{1/2}$ (c) $u = \left(\frac{E}{2m}\right)^{1/2}$ (d) $u = \left(\frac{E}{3m}\right)^{1/2}$

51. The correct order of acidic strength is

(a) $Cl_2O_7 > SO_2 > P_4O_{10}$ (b) $CO_2 > N_2O_5 > SO_3$

(c) $Na_2O > MgO > Al_2O_3$ (d) $K_2O > CaO > MgO$

52. Which of the following compounds exhibits stereoisomerism?

(a) 2-methyl-1-butene (b) 3-methyl-1-butyne

(c) 3-methylbutanoic acid (d) 2-methylbutanoic acid

53. The root-mean-square velocity of an ideal gas at constant pressure varies with its density d as

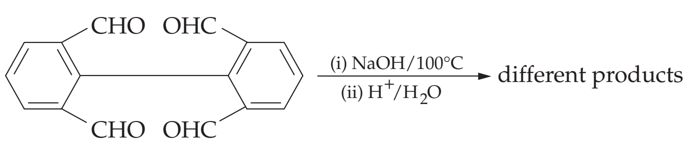
(a) d^2 (b) d (c) $\sqrt{d}$ (d) $\frac{1}{\sqrt{d}}$

54. The reaction $3ClO^-(aq) \rightarrow ClO_3^-(aq) + 2Cl^-(aq)$ is an example of

(a) oxidation reaction (b) reduction reaction

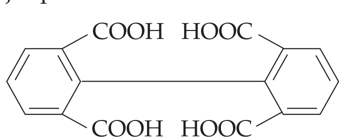
(c) disproportionation reaction (d) decomposition reaction

55.

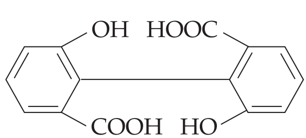


The major product of the above reaction is

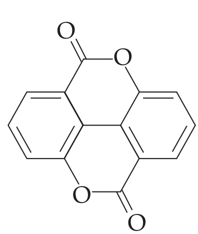
(a)

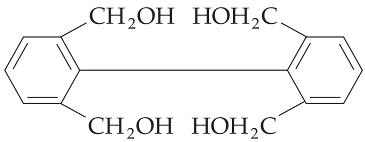


(b)



(c)



(d) 

56. When two reactants (A) and (B) are mixed to give the products (C) and (D), the reaction quotient (Q) at the initial stages of the reaction

(a) is zero (b) decreases with time

(c) is independent of time (d) increases with time

57. When temperature is increased, surface tension of water

(a) increases (b) decreases

(c) remains constant (d) shows irregular behaviour

58. Rutherford's experiment, which established the nuclear model of the atom, used a beam of

(a) β-particles, which impinged on a metal foil and got absorbed

(b) γ-rays, which impinged on a metal foil and ejected electrons

(c) helium atoms, which impinged on a metal foil and got scattered

(d) helium nuclei, which impinged on a metal foil and got scattered

59. $$Zn \mid Zn^{2+}(0.1\ M) \parallel Fe^{2+}(0.01\ M) \mid Fe.$$

The emf of the above cell is 0.2905 V. The equilibrium constant for the cell reactions is

(a) $10^{0.32/0.0591}$ (b) $10^{0.32/0.0295}$

(c) $10^{0.26/0.0295}$ (d) $e^{0.32/0.295}$

60. Saturated solutions of KNO_3 are used to make salt bridges because

(a) velocity of K^+ is greater than that of NO_3^-

(b) velocity of NO_3^- is greater than that of K^+

(c) velocities of K^+ and NO_3^- are nearly the same

(d) KNO_3 is highly soluble in water

61. During depression of freezing point in a solution, which of the following are in equilibrium?

(a) Liquid solvent, solid solvent

(b) Liquid solvent, solid solute

(c) Liquid solute, solid solute

(d) Liquid solute, solid solvent

62. H_3BO_3 is a

(a) monobasic and weak Lewis acid

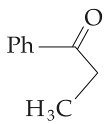
(b) monobasic and weak Brønsted acid

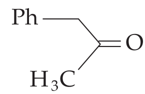
(c) monobasic and strong Lewis acid

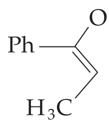
(d) tribasic and weak Brønsted acid

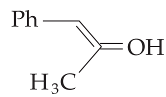
63. $$Ph{-}C{\equiv}C{-}CH_3 \xrightarrow{Hg^{2+}/H^+} (A).$$

In the above reaction, (A) is

(a) 

(b) 

(c) 

(d) 

64. Which of the following has the most acidic hydrogen?

(a) 3-hexanone (b) 2,4-hexanedione

(c) 2,5-hexanedione (d) 2,3-hexanedione

65. If the nitrogen atom had electronic configuration $1s^7$, it would have energy lower than that of the normal ground-state configuration $1s^2 2s^2 2p^3$ because the electrons would be closer to the nucleus. Yet, $1s^7$ is not observed because it violates

(a) the Heisenberg uncertainty principle

(b) the Hund rule

(c) the Pauli exclusion principle

(d) Bohr's postulate of stationary orbits

66. When phenyl magnesium bromide reacts with butanol, the product would be

(a) benzene (b) phenol

(c) *t*-butylbenzene (d) *t*-butyl phenyl ether

67. The two forms of D-glucopyranose obtained from the solution of D-glucose are called

(a) isomers (b) anomers (c) epimers (d) enantiomers

68. Which pair of compounds is expected to show similar colour in an aqueous medium?

(a) $FeCl_2$ and $CuCl_2$ (b) $VOCl_2$ and $CuCl_2$

(c) $VOCl_2$ and $FeCl_2$ (d) $FeCl_2$ and $MnCl_2$

69. Which kind(s) of isomerism is/are exhibited by octahedral $Co(NH_3)_4Br_2Cl$?

(a) Geometrical and ionization (b) Geometrical and optical

(c) Optical and ionization (d) Geometrical only

70. $MgSO_4$ on reaction with NH_4OH and Na_2HPO_4 forms a white crystalline precipitate. What is its formula?

(a) $Mg(NH_4)PO_4$ (b) $Mg_3(PO_4)_2$

(c) $MgCl_2 \cdot MgSO_4$ (d) $MgSO_4$

71. For a sparingly soluble salt A_pB_q, the relationship of its solubility product (K_s) with its solubility (S) is

(a) $K_s = S^{p+q} \cdot p^p \cdot q^q$ (b) $K_s = S^{p+q} \cdot p^q \cdot q^p$

(c) $K_s = S^{pq} \cdot p^p \cdot q^q$ (d) $K_s = S^{pq} \cdot (pq)^{p+q}$

72. Which of the folllwing reactions defines ΔH_f°?

(a) $C(diamond) + O_2(g) \rightarrow CO_2(g)$

(b) $\frac{1}{2} H_2(g) + \frac{1}{2} F_2(g) \rightarrow HF(g)$

(c) $N_2(s) + 3H_2(g) \rightarrow 2NH_3(g)$

(d) $CO(g) + \frac{1}{2} O_2(g) \rightarrow CO_2(g)$

73. ^{23}Na is the most stable isotope of Na. Find out the process by which $^{24}_{11}Na$ can undergo radioactive decay.

(a) β^- emission (b) α emission

(c) γ-ray emission (d) K-electron capture

74. Identify the correct order of boiling point of the following compounds:

(I) $CH_3CH_2CH_2CH_2OH$

(II) $CH_3CH_2CH_2CHO$

(III) $CH_3CH_2CH_2COOH$

(a) I > II > III (b) III > I > II

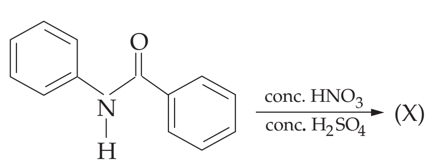
(c) I > III > II (d) III > II > I

75. The number of lone pair(s) in $XeOF_4$ is

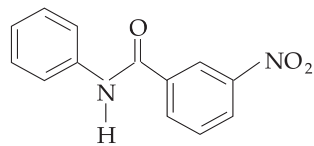
(a) zero (b) one

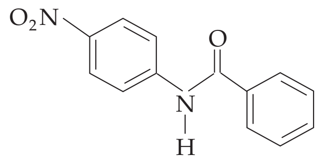
(c) two (d) three

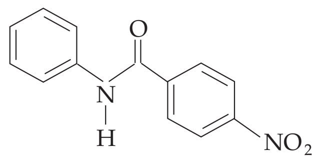
76.

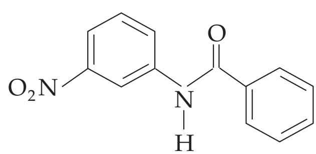


In the above reaction, the structure of the major product (X) is

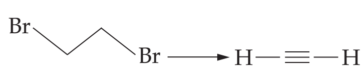
(a) 

(b) 

(c) 

(d) 

77. The reagent(s) for the conversion



is/are

(a) alcoholic KOH

(b) alcoholic KOH followed by $NaNH_2$

(c) aqueous KOH followed by $NaNH_2$

(d) Zn/CH_3OH

78. The number of structural isomers of C_6H_{14} is

(a) three (b) four

(c) five (d) six

79. The percentage of *p*-character in the orbital forming P—P bond in P_4 is

(a) 25 (b) 33

(c) 50 (d) 75

80. When 20 g naphthoic acid ($C_{11}H_8O_2$) is dissolved in 50 g benzene ($k_f = 1.72$ K kg mol^{-1}), a freezing-point depression of 2 K is observed. The van't Hoff factor (i) is

(a) 0.5 (b) 1 (c) 2 (d) 3

81. The value of $\log_{10}k$ for a reaction (A) $\rightleftharpoons$ (B) is (given that $\Delta_{fus}H^\circ_{296\ K} = -54.07$ kJ mol^{-1}, $\Delta_{fus}S^\circ_{296\ K} = -10$ J K^{-1} mol^{-1} and $R = 8.314$ J K^{-1} mol^{-1})

(a) 5 (b) 10

(c) 95 (d) 100

Answers

1. d	**2.** c	**3.** a	**4.** d	**5.** a
6. a	**7.** a	**8.** a	**9.** a	**10.** c
11. b	**12.** c	**13.** d	**14.** d	**15.** d
16. b	**17.** a			

18. (i) $\leftrightarrow$ b (ii) $\leftrightarrow$ c (iii) $\leftrightarrow$ a (iv) $\leftrightarrow$ c

19. b	**20.** c	**21.** c		

22. (i) $\leftrightarrow$ c (ii) $\leftrightarrow$ b (iii) $\leftrightarrow$ a (iv) $\leftrightarrow$ d

23. a	**24.** a	**25.** d	**26.** b	**27.** b
28. d	**29.** b	**30.** b	**31.** b	**32.** c
33. b	**34.** b	**35.** b	**36.** b	**37.** b
38. b	**39.** a	**40.** a	**41.** b	**42.** c
43. c	**44.** b	**45.** a	**46.** d	**47.** c
48. d	**49.** b	**50.** a	**51.** a	**52.** d
53. d	**54.** c	**55.** c	**56.** d	**57.** b
58. d	**59.** b	**60.** c	**61.** a	**62.** a
63. a	**64.** b	**65.** c	**66.** a	**67.** b
68. b	**69.** a	**70.** a	**71.** a	**72.** b
73. a	**74.** b	**75.** b	**76.** b	**77.** b
78. c	**79.** d	**80.** a	**81.** b	

❑

7

IIT Questions—4

1. 2.5 mL of a $\frac{2}{5}$ M weak monoacidic base ($K_b = 1 \times 10^{-12}$ at 25°C) is titrated with $\frac{2}{15}$ M HCl in water at 25°C. The concentration of H^+ at equivalence point is ($K_w = 1 \times 10^{-14}$ at 25°C)

(a) 3.7×10^{-13} mol L^{-1} (b) 3.2×10^{-7} mol L^{-1}
(c) 3.2×10^{-2} mol L^{-1} (d) 2.7×10^{-2} mol L^{-1}

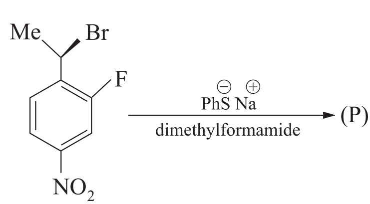
2. Native silver forms a water-soluble complex with a dilute aqueous solution of NaCN in the presence of

(a) nitrogen (b) oxygen
(c) carbon dioxide (d) argon

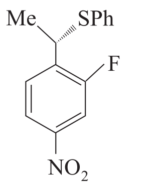
3. Under the same reaction conditions, the initial concentration of 1.386 mol dm^{-3} of a substance becomes half in 40 seconds and 20 seconds through first-order and zero-order kinetics, respectively. The ratio, k_1/k_0, of the rate constants for the first order and zero order of the reactions is

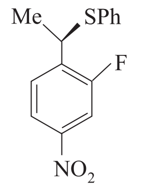
(a) 0.5 mol^{-1} dm^3 (b) 1.0 mol dm^{-3}
(c) 1.5 mol dm^{-3} (d) 2.0 mol^{-1} dm^3

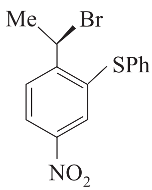
4.

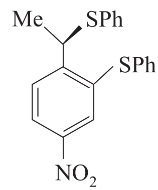


The major product of the above reaction is

(a) 

(b) 

(c) 

(d) 

5. The aqueous solution of $Na_2S_2O_3$ on reaction with Cl_2 gives

(a) $Na_2S_4O_6$
(b) $NaHSO_4$
(c) NaCl
(d) NaOH

6. Hyperconjugation involves overlap of the orbitals

(a) σ and σ
(b) σ and p
(c) p and p
(d) π and π

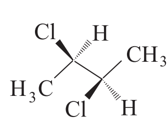
7. A gas described by the van der Waals equation

(a) behaves similar to an ideal gas in the limit of large molar volumes
(b) behaves similar to an ideal gas in the limit of large pressure
(c) is characterised by van der Waals coefficients that are dependent on the identity of the gas but are independent of the temperature
(d) has the pressure that is lower than the presure exerted by the same gas behaving ideally

8. A solution of a colourless salt (H) on boiling with excess NaOH produces a nonflammable gas. The gas evolution ceases after some time. Upon addition of Zn dust to the same solution, the gas evolution restarts. The colourless salt(s) (H) is/are

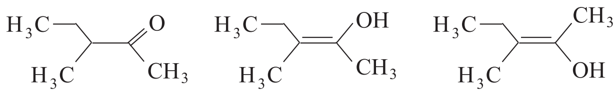
(a) NH_4NO_3
(b) NH_4NO_2
(c) NH_4Cl
(d) $(NH_4)_2SO_4$

9.



Which is/are the correct statement(s) about the above compound?

(a) The compound is optically active.
(b) The compound possesses a centre of symmetry.
(c) The compound possesses a plane of symmetry.
(d) The compound possesses an axis of symmetry.

10. 

(E) (F) (G)

Which is/are the correct statement(s) concerning the structures (E), (F) and (G)?

(a) (E), (F) and (G) are resonance structures.

(b) (E), (F) and (E), (G) are tautomers.

(c) (F) and (G) are geometrical isomers.

(d) (F) and (G) are diastereomers.

11. Among the following, the surfactant that will form micelles in aqueous solution at the lowest molar concentration at ambient conditions is

(a) $CH_3(CH_2)_{15}N^+(CH_3)_3Br^-$ (b) $CH_3(CH_2)_{11}OSO_3^-Na^+$

(c) $CH_3(CH_2)_6COO^-Na^+$ (d) $CH_3(CH_2)_{11}N^+(CH_3)_3Br^-$

12. The solubility product constants (K_{sp}) of salts of types MX, MX_2 and M_3X at temperature T are 4.0×10^{-8}, 3.2×10^{-14} and 2.7×10^{-15}, respectively. The solubilities (in mol dm^{-3}) of the salts at temperature T are in the order

(a) $MX > MX_2 > M_3X$ (b) $M_3X > MX_2 > MX$

(c) $MX_2 > M_3X > MX$ (d) $MX > M_3X > MX_2$

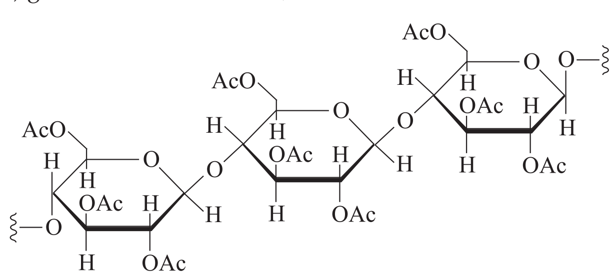
13. Electrolysis of dilute aqueous NaCl solution was carried out by passing 10 mA current. The time required to liberate 0.01 mol of H_2 gas at the cathode is (given that Faraday constant = 96500 C mol^{-1})

(a) 9.65×10^4 s (b) 19.3×10^4 s

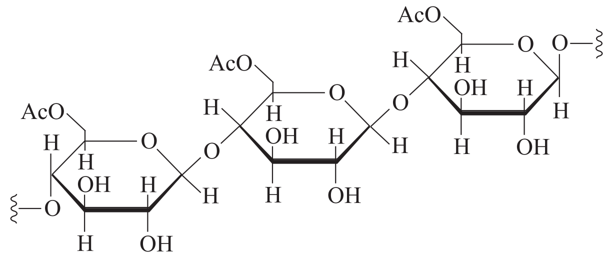
(c) 28.95×10^4 s (d) 38.6×10^4 s

14. Cellulose upon acetylation with excess acetic anhydride/H_2SO_4 (catalytic) gives cellulose triacetate, whose structure is

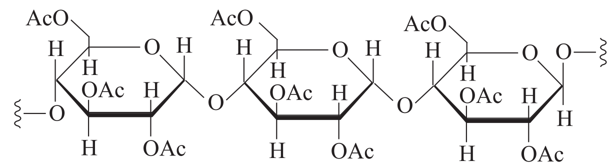
(a)



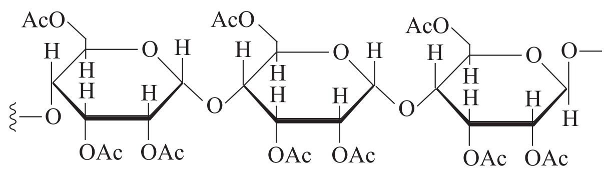
(b)



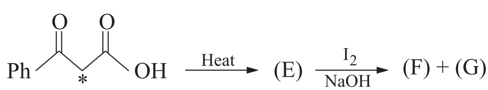
(c)



(d)



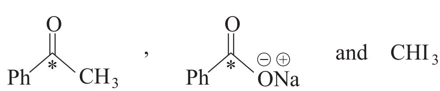
15.



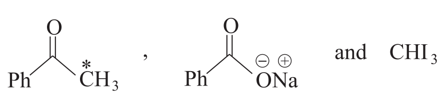
(* implies ^{13}C labelled carbon)

In the above reaction sequence, the correct structures of (E), (F) and (G) are respectively

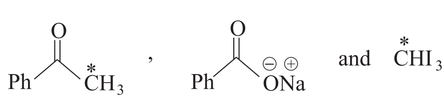
(a)



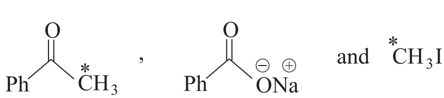
(b)

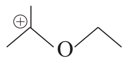
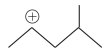
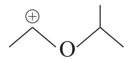
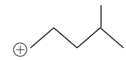


(c)



(d)



16.    

(I) (II) (III) (IV)

The correct stability order for the above set of species is

(a) (II) > (IV) > (I) > (III)
(b) (I) > (II) > (III) > (IV)
(c) (II) > (I) > (IV) > (III)
(d) (I) > (III) > (II) > (IV)

17. Which is a coloured compound among the following?

(a) $CuCl$
(b) $K_3[Cu(CN)_4]$
(c) CuF_2
(d) $[Cu(CH_3CN)_4]BF_4$

18. The IUPAC name for $[Ni(NH_3)_4]$ $[NiCl_4]$ is

(a) tetrachloronickel(II) tetraamminenickelate(II)
(b) tetraamminenickel(II) tetrachloronickelate(II)
(c) tetraamminenickel(II) tetrachloronickelate(II)
(d) tetrachloronickel(II) tetraamminenickelate(0)

19. Both $[Ni(CO)_4]$ and $[Ni(CN)_4]^{2-}$ are diamagnetic. The hybridisations of nickel in these complexes, respectively, are

(a) sp^3 and sp^3
(b) sp^3 and dsp^2
(c) dsp^2 and sp^3
(d) dsp^2 and dsp^2

20. STATEMENT-1: Pb^{4+} compounds are stronger oxidizing agents than Sn^{4+} compounds.

STATEMENT-2: The higher oxidation states for the group 14 elements are more stable for the heavier members of the group due to inert-pair effect.

(a) Statement-1 is True, Statement-2 is True; Statement-2 **is** a correct explanation for Statement-1.
(b) Statement-1 is True, Statement-2 is True; Statement-2 **is not** a correct explanation for Statement-1.
(c) Statement-1 is True, Statement-2 is False.
(d) Statement-1 is False, Statement-2 is True.

21. STATEMENT-1: The plot of atomic number (y-axis) versus number of neutrons (x-axis) for stable nuclei shows a curvature towards the x-axis from the line of 45° slope as the atomic number is increased.

STATEMENT-2: Proton-proton electrostatic repulsions begin to overcome attractive forces involving protons and neutrons in heavier nuclides.

(a) Statement-1 is True, Statement-2 is True; Statement-2 **is** a correct explanation for Statement-1.

(b) Statement-1 is True, Statement-2 is True; Statement-2 **is not** a correct explanation for Statement-1.

(c) Statement-1 is True, Statement-2 is False.

(d) Statement-1 is False, Statement-2 is True.

22. STATEMENT-1: Bromobenzene upon reaction with Br_2/Fe gives 1,4-dibromobenzene as the major product.

STATEMENT-2: In bromobenzene, the inductive effect of the bromo group is more dominant than the mesomeric effect directing the incoming electrophile.

(a) Statement-1 is True, Statement-2 is True; Statement-2 **is** a correct explanation for Statement-1.

(b) Statement-1 is True, Statement-2 is True; Statement-2 **is not** a correct explanation for Statement-1.

(c) Statement-1 is True, Statement-2 is False.

(d) Statement-1 is False, Statement-2 is True.

23. STATEMENT-1: For every chemical reaction at equilibrium, standard Gibbs energy of reaction is zero.

STATEMENT-2: At constant temperature and pressure, chemical reactions are spontaneous in the direction of decreasing Gibbs energy.

(a) Statement-1 is True, Statement-2 is True; Statement-2 **is** a correct explanation for Statement-1.

(b) Statement-1 is True, Statement-2 is True; Statement-2 **is not** a correct explanation for Statement-1.

(c) Statement-1 is True, Statement-2 is False.

(d) Statement-1 is False, Statement-2 is True.

24. STATEMENT-1: Aniline on reaction with $NaNO_2/HCl$ at 0°C followed by coupling with β-naphthol gives a dark blue precipitate.

STATEMENT-2: The colour of the compound formed in the reaction of aniline with $NaNO_2/HCl$ at 0°C followed by coupling with β-naphthol is due to the extended conjugation.

(a) Statement-1 is True, Statement-2 is True; Statement-2 **is** a correct explanation for Statement-1.

(b) Statement-1 is True, Statement-2 is True; Statement-2 **is not** a correct explanation for Statement-1.

(c) Statement-1 is True, Statement-2 is False.

(d) Statement-1 is False, Statement-2 is True.

25. STATEMENT-1: The geometrical isomers of the complex $[M(NH_3)_4Cl_2]$ are optically inactive.

STATEMENT-2: Both geometrical isomers of the complex $[M(NH_3)_4Cl_2]$ possess an axis of symmetry.

(a) Statement-1 is True, Statement-2 is True; Statement-2 **is** a correct explanation for Statement-1.

(b) Statement-1 is True, Statement-2 is True; Statement-2 **is not** a correct explanation for Statement-1.

(c) Statement-1 is True, Statement-2 is False.

(d) Statement-1 is False, Statement-2 is True.

26. STATEMENT-1: There is a natural asymmetry between converting work to heat and converting heat to work.

STATEMENT-2: No process is possible in which the sole result is the absorption of heat from a reservoir and its complete conversion into work.

(a) Statement-1 is True, Statement-2 is True; Statement-2 **is** a correct explanation for Statement-1.

(b) Statement-1 is True, Statement-2 is True; Statement-2 **is not** a correct explanation for Statement-1.

(c) Statement-1 is True, Statement-2 is False.

(d) Statement-1 is False, Statement-2 is True.

27. STATEMENT-1: $[Fe(H_2O)_5NO]SO_4$ is paramagnetic.

STATEMENT-2: The Fe in $[Fe(H_2O)_5NO]SO_4$ has three unpaired electrons.

(a) Statement-1 is True, Statement-2 is True; Statement-2 **is** a correct explanation for Statement-1.

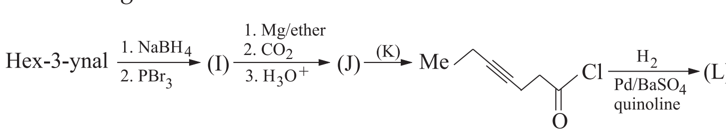
(b) Statement-1 is True, Statement-2 is True; Statement-2 **is not** a correct explanation for Statement-1.

(c) Statement-1 is True, Statement-2 is False.

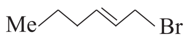
(d) Statement-1 is False, Statement-2 is True.

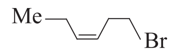
Answer the questions below (28-30) using the following information.

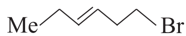
In the following reaction sequence, products (I), (J) and (L) are formed. (K) represents a reagent.

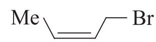


28. The structure of the product (I) is

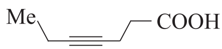
(a) 

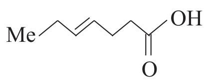
(b) 

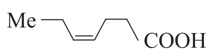
(c) 

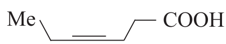
(d) 

29. The structures of the compounds (J) and (K) are respectively.

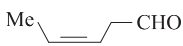
(a)  and $SOCl_2$

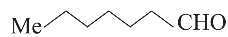
(b)  and SO_2Cl_2

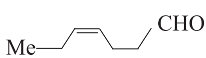
(c)  and $SOCl_2$

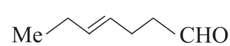
(d)  and CH_3SO_2Cl

30. The structure of the product (L) is

(a) 

(b) 

(c) 

(d) 

Answer the questions below (31–33) using the following information.

There are some deposits of nitrates and phosphates in earth's crust. Nitrates are more soluble in water. Nitrates are difficult to reduce under the laboratory conditions but microbes do it easily. Ammonia forms large number of complexes with transition metal ions. Hybridization easily explains the ease of sigma donation capability of NH_3 and PH_3. Phosphine is a flammable gas and is prepared from white phosphorous.

31. Which is the correct statement among the following?

(a) Phosphates have no biologial significance in humans.

(b) Between nitrates and phosphates, phosphates are less abundant in earth's crust.

(c) Between nitrates and phosphates, nitrates are less abundant in earth's crust.

(d) Oxidation of nitrates is possible in soil.

32. Which is the correct statement among the following?

(a) Between NH_3 and PH_3, NH_3 is a better electron donor because the lone pair of electrons occupies a spherical s orbital and is less directional.

(b) Between NH_3 and PH_3, PH_3 is a better electron donor because the lone pair of electrons occupies an sp^3 orbital and is more directional.

(c) Between NH_3 and PH_3, NH_3 is a better electron donor because the lone pair of electrons occupies an sp^3 orbital and is more directional.

(d) Between NH_3 and PH_3, PH_3 is a better electron donor because the lone pair of electrons occupies a spherical s orbital and is less directional.

33. White phosphorus on reaction with NaOH gives PH_3 as one of the products. This is a

(a) dimerization reaction (b) disproportionation reaction

(c) condensation reaction (d) precipitation reaction

Answer the questions below (34–36) using the following information.

Properties such as the boiling point, freezing point and vapour pressure of a pure solvent change when solute molecules are added to get a homogeneous solution. These are called colligative properties. Applications of colligative properties are very useful in our day-to-day life. One of its examples is the use of ethylene glycol and water mixture as an antifreezing liquid in the radiator of automobiles.

A solution (M) is prepared by mixing ethanol and water. The mole fraction of ethanol in the mixture is 0.9

Given: Freezing point depression constant of water (K_f^{water}) = 1.86 K kg mol^{-1}

Freezing point depression constant of ethanol ($K_f^{ethanol}$) = 2.0 K kg mol^{-1}

Boiling point elevation constant of water (K_b^{water}) = 0.52 K kg mol^{-1}

Boiling point elevation constant of ethanol ($K_b^{ethanol}$) = 1.2 K kg mol^{-1}

Standard freezing point of water = 273 K

Standard freezing point of ethanol = 155.7 K

Standard boiling point of water = 373 K

Standard boiling point of ethanol = 351.5 K

Vapour pressure of pure water = 32.8 mm Hg

Vapour pressure of pure ethanol = 40 mm Hg

Molecular weight of water = 18 mol^{-1}

Molecular weight of ethanol = 46 mol^{-1}

In answering the following questions, consider the solution to be ideal dilute solutions and solutes to be nonvolatile and nondissociative.

34. The freezing point of the solution (M) is

(a) 268.7 K (b) 268.5 K

(c) 234.2 K (d) 150.9 K

35. The vapour pressure of the solution (M) is

(a) 39.3 mmHg (b) 36.0 mmHg

(c) 29.5 mmHg (d) 28.8 mmHg

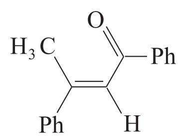
36. Water is added to the solution (M) such that the mole fraction of water in the solution becomes 0.9. The boiling point of this solution is

(a) 380.4 K (b) 376.2 K

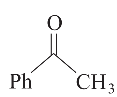
(c) 375.5 K (d) 354.7 K

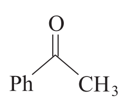
Answer the questions below (37–39) using the following information.

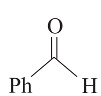
A tertiary alcohol (H) upon acid-catalysed dehydration gives a product (I). Ozonolysis of (I) leads to the compounds (J) and (K). The compound J upon reaction with KOH gives benzyl alcohol and a compound (L), whereas (K) on reaction with KOH gives only (M).

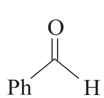
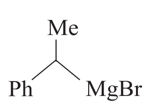
(M) : 

37. The compound (H) is formed by the reaction of

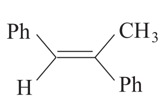
(a)  + PhMgBr

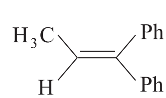
(b)  + $PhCH_2MgBr$

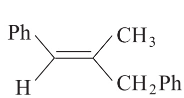
(c)  + $PhCH_2MgBr$

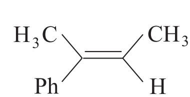
(d)  + 

38. The structure of the compound (I) is

(a) 

(b) 

(c) 

(d) 

39. The structures of the compounds (J), (K) and (L) are respectively

(a) $PhCOCH_3$, $PhCH_2COCH_3$ and $PhCH_2COO^-K^+$
(b) $PhCHO$, $PhCH_2CHO$ and $PhCOO^-K^+$
(c) $PhCOCH_3$, $PhCH_2CHO$ and $CH_3COO^-K^+$
(d) $PhCHO$, $PhCOCH_3$ and $PhCOO^-K^+$

Answer the questions below (40–42) using the following information.

In the hexagonal system of crystals, a frequently encountered arrangement of atoms is described as a hexagonal prism. Here, the top and bottom of the cell are regular hexagons and three atoms are sandwiched between them. A space-filling model of this structure, called the *hexagonal close-packed* (hcp) structure, is constituted of a sphere on a flat surface surrounded in the same plane by six identical spheres as closely as possible. Three spheres are then placed over the first layer so that they touch each other and represent the second layer. Each one of these three spheres touches three spheres of the bottom layer. Finally,the second layer is covered with a third layer that is identical to the bottom layer in relative position. Assume radius of every sphere to be r.

40. The number of atoms in this hcp unit cell is

(a) 4 (b) 6 (c) 12 (d) 17

41. The volume of this hcp unit cell is

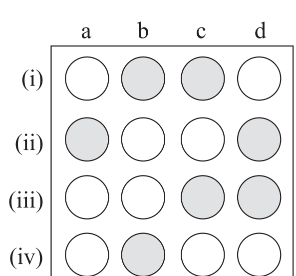
(a) $24\sqrt{2}\,r^3$ (b) $16\sqrt{2}\,r^3$ (c) $12\sqrt{2}\,r^3$ (d) $\frac{64}{3\sqrt{3}}\,r^3$

42. The empty space in this hcp unit cell is

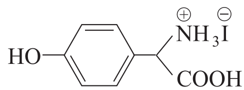
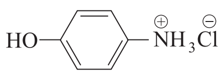
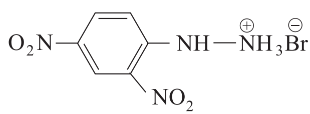
(a) 74% (b) 47.6% (c) 32% (d) 26%

This section contains three questions (43–45). Each question contains statements given in two columns, which have to be matched. Statements in column A are labelled (i), (ii), (iii) and (iv), whereas statements in column B are labelled (a), (b), (c) and (d). The answers to these questions have to be appropriately bubbled, as illustrated in the following example.

If the correct matches are (i) ↔ b, (i) ↔ c, (ii) ↔ a, (ii) ↔ d, (iii) ↔ c, (iii) ↔ d and (iv) ↔ b then the correctly bubbled matrix will look like the following.



43.

Column A	*Column B*
(i) $H_2N-\overset{\oplus}{N}H_3\overset{\ominus}{Cl}$	(a) sodium fusion extract of the compound gives Prussian blue colour with $FeSO_4$
(ii) 	(b) gives positive $FeCl_3$ test
(iii) 	(c) gives white precipitate with $AgNO_3$
(iv) 	(d) reacts with aldehydes to form the corresponding hydrazone derivative

44.

Column A	*Column B*
(i) Orbital angular momentum of the electron in a hydrogenlike atomic orbital	(a) Principal quantum number
(ii) A hydrogenlike one-electron wave function obeying the Pauli principle	(b) Azimuthal quantum number
(iii) Shape, size and orientation of hydrogenlike atomic orbitals	(c) Magnetic quantum number
(iv) Probability density of electrons at the nucleus in hydrogenlike atoms	(d) Spin quantum number

45.

Column A	*Column B*
(i) $PbS \rightarrow PbO$	(a) Roasting
(ii) $CaCO_3 \rightarrow CaO$	(b) Calcination
(iii) $ZnS \rightarrow Zn$	(c) Carbon reduction
(iv) $Cu_2S \rightarrow Cu$	(d) Self-reduction

Answers

1. d	**2.** b	**3.** a	**4.** a	**5.** b
6. b	**7.** a, c, d	**8.** a, b	**9.** a, d	**10.** b, c, d
11. c	**12.** d	**13.** b	**14.** a	**15.** c
16. d	**17.** c	**18.** c	**19.** b	**20.** c
21. a	**22.** c	**23.** d	**24.** d	**25.** b
26. b	**27.** a	**28.** d	**29.** c	**30.** c
31. c	**32.** c	**33.** b	**34.** d	**35.** b
36. b	**37.** b	**38.** a	**39.** d	**40.** b
41. a	**42.** d			

43.

	a	b	c	d
(i)	○	○	●	●
(ii)	●	●	○	○
(iii)	●	●	●	○
(iv)	●	○	○	●

44.

	a	b	c	d
(i)	○	●	○	○
(ii)	○	○	○	●
(iii)	●	●	●	○
(iv)	●	●	●	○

45.

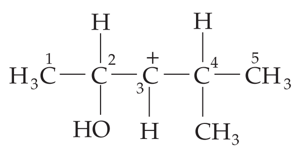
	a	b	c	d
(i)	●	○	○	○
(ii)	○	●	○	○
(iii)	●	○	●	○
(iv)	●	○	○	●

❑

8

IIT Questions—5

1. In the following carbocation, which is the most likely to migrate to the positively charged carbon?



(a) CH_3 at C-4 (b) H at C-4

(c) CH_3 at C-2 (d) H at C-2

2. For a first-order reaction $A \rightarrow P$, the temperature (T)-dependent rate constant (k) was found to follow the equation $\log k = -(2000)\frac{1}{T} + 6.0$. The pre-exponential factor A and the activation energy E_a, respectively, are

(a) $1.0 \times 10^6\ s^{-1}$ and 9.2 kJ mol^{-1}

(b) $6.0\ s^{-1}$ and 16.6 kJ mol^{-1}

(c) $1.0 \times 10^6\ s^{-1}$ and 16.6 kJ mol^{-1}

(d) $1.0 \times 10^6\ s^{-1}$ and 38.3 kJ mol^{-1}

3. Given that the abundances of isotopes ^{54}Fe, ^{56}Fe and ^{57}Fe are 5%, 90% and 5% respectively, the atomic mass of Fe is

(a) 55.85 (b) 55.95

(c) 55.75 (d) 56.05

4. Among the following, the polymer in which the intermolecular force of attraction is the weakest is

(a) nylon (b) polyvinyl chloride

(c) cellulose (d) natural rubber

5. The Henry's law constant for the solubility of N_2 gas in water at 298 K is 1.0×10^5 atm. The mole fraction of N_2 in air is 0.8. The number of moles of N_2 from air dissolved in 10 moles of water at 298 K and 5 atm pressure is

(a) 4.0×10^{-4} (b) 4.0×10^{-5} (c) 5.0×10^{-4} (d) 4.0×10^{-6}

6. I_2 is obtained from IO_3^- by reduction with

(a) HCO_3^- (b) H_2O_2

(c) HSO_3^- (d) HNO_2

7. The spin only magnetic moment value (in Bohr magneton units) of $Cr(CO)_6$ is

(a) 0 (b) 2.84 (c) 4.90 (d) 5.92

8. The correct order of stability of the resonance structures

$$H_2C=\overset{+}{N}=\overset{-}{N} \qquad H_2\overset{+}{C}-N=\overset{-}{N} \qquad H_2\overset{-}{C}-\overset{+}{N}\equiv N \qquad H_2\overset{-}{C}-N=\overset{+}{N}$$

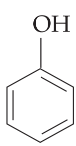
(I) (II) (III) (IV)

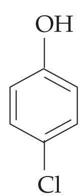
is

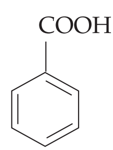
(a) (I) > (II) > (IV) > (III) (b) (I) > (III) > (II) > (IV)

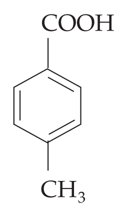
(c) (II) > (I) > (III) > (IV) (d) (III) > (I) > (IV) > (II)

9. The correct order of acidity of


(I)


(II)


(III)


(IV)

is

(a) (III) > (IV) > (II) > (I) (b) (IV) > (III) > (I) > (II)

(c) (III) > (II) > (I) > (IV) (d) (II) > (III) > (IV) > (I)

10. Among the electrolytes Na_2SO_4, $CaCl_2$, $Al_2(SO_4)_3$ and NH_4Cl, the most effective coagulating agent for Sb_2S_3 sol is

(a) Na_2SO_4 (b) $CaCl_2$ (c) $Al_2(SO_4)_3$ (d) NH_4Cl

11. The reaction of P_4 with X leads selectively to P_4O_6. X is

(a) dry O_2

(b) a mixture of O_2 and N_2

(c) moist O_2

(d) O_2 in the presence of aqueous NaOH

12. Which of the following is not applicable to physical adsorptions?

(a) Adsorption on solids is reversible.

(b) Adsorption increases with increase in temperature.
(c) Adsorption is spontaneous.
(d) Both the enthalpy and entropy of adsorption are negative.

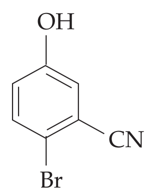
13. Among the following, the complex likely to show optical activity is

(a) *trans*–$[Co(NH_3)_4Cl_2]$ (b) $[Cr(H_2O)_6]^{3+}$
(c) *cis*–$[Co(NH_3)_4Cl_2]$ (d) $[Pt(NH_3)_3Br_3]^+$

14. The term that corrects for the attractive forces present in a real gas in the van der Waals equation is

(a) nb (b) $\frac{an^2}{V^2}$ (c) $-\frac{an^2}{V^2}$ (d) $-nb$

15. The IUPAC name of



is

(a) 4-bromo-3-cyanophenol
(b) 2-bromo-5-hydroxybenzonitrile
(c) 2-cyano-4-hydroxybromobenzene
(d) 6-bromo-3-hydroxybenzonitrile

16. The compound(s) formed upon the combustion of sodium metal in an excess of air is(are)

(a) Na_2O_2 (b) Na_2O
(c) NaO_2 (d) $NaOH$

17. Which of the following statement(s) regarding defects in solids is(are) correct?

(a) A Frenkel defect is usually favoured by a very small difference in the size of the cation and anion.
(b) A Frenkel defect is a dislocation defect.
(c) The trapping of an electron in the lattice leads to the formation of an F-centre.
(d) Schottky defects have no effect on the physical properties of solids.

18. Which of the following compounds exhibit(s) geometrical isomerism?

(a) $[Pt(en)Cl_2]$ (b) $[Pt(en)_2]\ Cl_2$
(c) $[Pt(en)_2\ Cl_2]Cl_2$ (d) $[Pt(NH_3)_2Cl_2]$

19. Which of the following statements is(are) correct about the compound $H_3C(HO)HC{-}CH{=}CH{-}CH(OH)CH_3$ (X)?

(a) The total number of stereoisomers possible for X is 6.

(b) The total number of diastereomers possible for X is 3.

(c) If the stereochemistry about the double bond in X is *trans*, the number of enantiomers possible for X is 4.

(d) If the stereochemistry about the double bond in X is *cis*, the number of enantiomers possible for X is 2.

20. In the reaction

$$2X + B_2H_6 \rightarrow [BH_2(X)_2]^+ [BH_4]^-$$

the amine(s) X is(are)

(a) NH_3 (b) CH_3NH_2

(c) $(CH_3)_2NH$ (d) $(CH_3)_3N$

21. Among the following, which is(are) state function(s)

(a) Internal energy (b) Irreversible expansion work

(c) Reversible expansion work (d) Molar enthalpy

22. For the reduction of NO_3^- ion in an aqueous solution, E^0 is + 0.96 V values of E^0 for some metal ions are given below.

$V^{2+}(aq) + 2e^- \rightarrow V$ $E^0 = -1.19$ V

$Fe^{3+}(aq) + 3e^- \rightarrow Fe$ $E^0 = -0.04$ V

$Au^{3+}(aq) + 3e^- \rightarrow Au$ $E^0 = +1.40$ V

$Hg^{2+}(aq) + 2e^- \rightarrow Hg$ $E^0 = +0.86$ V

The pair(s) of metals that is(are) oxidized by NO_3^- in an aqueous solution is(are)

(a) V and Hg (b) Hg and Fe

(c) Fe and Au (d) Fe and V

23. Which of the following are the amide derivatives of monoamino dicarboxylic acid?

(a) Asparagine (b) Lysine

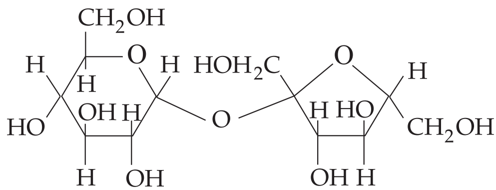
(c) Proline (d) Glutamine

24. The nitrogen oxide(s) that contain(s) N — N bond(s) is(are)

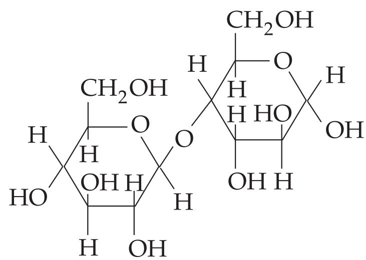
(a) N_2O (b) N_2O_3

(c) N_2O_4 (d) N_2O_5

25. For sugars X and Y (shown below), which of the given statements is(are) correct?



X



Y

(a) X is a reducing sugar and Y is a nonreducing sugar.

(b) X is a nonreducing sugar and Y is a reducing sugar.

(c) The glucosidic linkages in X and Y are α and β respectively.

(d) The glucosidic linkages in X and Y are β and α respectively.

26. C_V and C_p denote the molar specific heat capacities of a gas at constant volume and constant pressure respectively. Which of the following statements is(are) correct?

(a) $C_p - C_V$ is larger for a diatomic ideal gas than for a monoatomic ideal gas.

(b) $C_p + C_V$ is larger for a diatomic ideal gas than for a monoatomic ideal gas.

(c) C_p/C_V is larger for a diatomic ideal gas than for a monoatomic ideal gas.

(d) $C_p \cdot C_V$ larger for a diatomic ideal gas than for a monoatomic ideal gas.

27. Match List I (reactions) with List II (reagents) and select the correct answer using the codes given below the lists.

List I (reactions)	List II (reagents)
(A) Wolff–Kishner reduction	1. NaCN
(B) Witting reaction	2. $Ph_3P = CHR$

(C) Benzoin condensation	3. Concentrated NaOH
(D) Cannizzaro reaction	4. N_2H_4, KOH
	5. NaOBr

Codes:

(a) A B C D
4 3 2 1

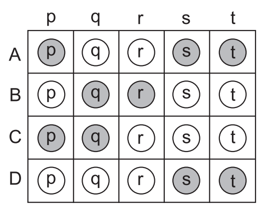
(b) A B C D
1 2 5 3

(c) A B C D
4 2 1 3

(d) A B C D
1 3 5 2

Questions 28 through 31 contain two columns, which have to be matched. The items in **Column I** are labelled A, B, C and D, while those in **Column II** are labelled p, q, r, s and t. Any given item in **Column I** can match **ONE OR MORE** in **Column II.** The appropriate bubbles corresponding to the answers to these questions have to be darkened as illustrated in the following example.

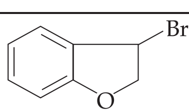
If the correct matches are A – p and t; B – q and r; C – p and q; and D – s and t; the bubbles should be darkened as follows.

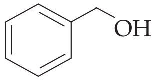
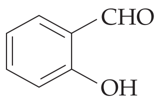
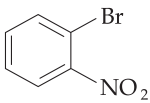


28. Match each of the reactions given in **Column I** with the corresponding product(s) given in **Column II.**

Column I	Column II
(A) Cu + dil.HNO_3	(p) NO
(B) Cu + conc. HNO_3	(q) NO_2
(C) Zn + dil. HNO_3	(r) N_2O
(D) Zn + conc. HNO_3	(s) $Cu(NO_3)_2$
	(t) $Zn(NO_3)_2$

29. Match each of the compounds given in **Column I** with the reaction(s) that they can undergo, given in **Column II.**

Column I	Column II
(A) 	(p) Nucleophilic substitution

(B) 	(q) Elimination
(C) 	(r) Nucleophilic addition
(D) 	(s) Esterification with acetic Anhydride
	(t) Dehydrogenation

30. Match each of the diatomic molecules in **Column I** with its property/properties in **Column II.**

Column I	Column II
(A) B_2	(p) Paramagnetic
(B) N_2	(q) Undergoes oxidation
(C) O_2^-	(r) Undergoes reduction
(D) O_2	(s) Bond order ≥ 2
	(t) Mixing of s and p orbitals

31. Match each of the compounds in **Column I** with its characteristics reaction(s) in **Column II.**

Column I	Column II
(A) $CH_3CH_2CH_2CN$	(p) Reduction with $Pd - C/H_2$
(B) $CH_3CH_2OCOCH_3$	(q) Reduction with $SnCl_2/HCl$
(C) $CH_3—CH=CH—CH_2OH$	(r) Development of foul smell on treatment with chloroform and alcoholic KOH
(D) $CH_3CH_2CH_2CH_2NH_2$	(s) Reduction with diisobutyl-aluminium hydride (DIBAL-H)
	(t) Alkaline hydrolysis

Answer questions (32–34) using the following information.

p-Amino-*N*, *N*-dimethylaniline is added to a strongly acidic solution of X. The resulting solution is treated with a few drops of an aqueous solution of Y to yield a blue coloration due to the formation of methylene blue. Treatment of the aqueous solution of Y with the reagent potassium hexacyanoferrate(II) leads to the formation of an intense blue precipitate. The precipitate dissolves on excess addition of the reagent. Similarly, treatment of the solution of Y with the solution of potassium hexacyanoferrate(III) leads to a brown coloration due to the formation of Z.

32. The compound X is

(a) $NaNO_3$ (b) $NaCl$

(c) Na_2SO_4 (d) Na_2S

33. The compound Y is

(a) $MgCl_2$ (b) $FeCl_2$

(c) $FeCl_3$ (d) $ZnCl_2$

34. The compound Z is

(a) $Mg_2[Fe(CN)_6]$ (b) $Fe[Fe(CN)_6]$

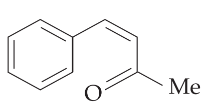
(c) $Fe_4[Fe(CN)_6]_3$ (d) $K_2Zn_3[Fe(CN)_6]_2$

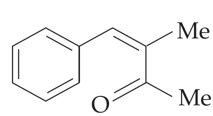
Answer questions 35–37 using the following information.

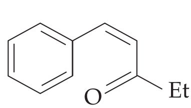
A carbonyl compound **P**, which responds positively to the iodoform test, reacts with MeMgBr followed by dehydration to give an olefin **Q**. Ozonolysis of **Q** leads to the formation of a dicarbonyl compound **R**, which undergoes an intramolecular aldol reaction to give predominantly **S**.

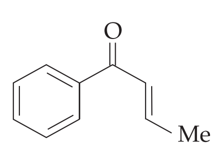
$$P \xrightarrow[\substack{2.\ H^+.\ H_2O\\ 3.\ H_2SO_4,\ \Delta}]{1.\ MeMgBr} Q \xrightarrow[2.\ Zn,\ H_2O]{1.\ O_3} R \xrightarrow[2.\ \Delta]{1.\ OH^-} S$$

35. The structure of the carbonyl compound. P is

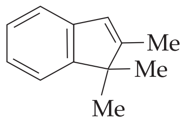
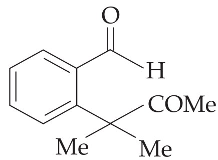
(a) 

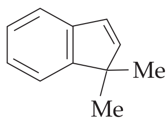
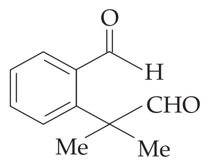
(b) 

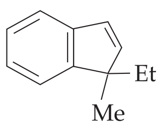
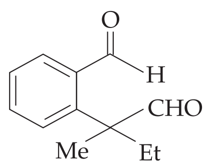
(c) 

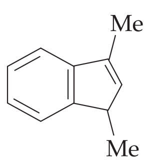
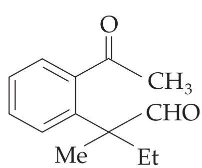
(d) 

36. The structures of the products Q and R, respectively, are

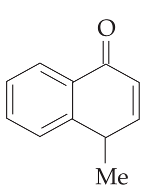
(a)  , 

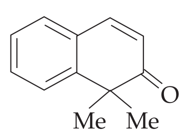
(b)  , 

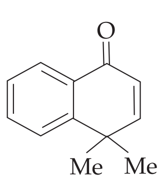
(c)  , 

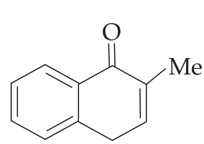
(d)  , 

37. The structure of the product S is

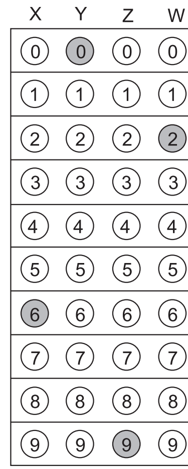
(a) 

(b) 

(c) 

(d) 

The answer to each of the questions (38–45) is a single-digit integer, ranging from 0 to 9. The appropriate bubbles below the respective question numbers in the ORS have to be darkened. For example, if the correct answers to question numbers X, Y, Z and W (say) are 6, 0, 9 and 2, respectively, the bubbles should be darkened as follows.



38. The dissociation constant of a substituted benzoic acid at 25°C is 1.0×10^{-4}. The pH of a 0.01 M solution of its sodium salt is

39. At 400 K, the root mean square (rms) speed of a gas X (molecular weight $= 40$) is equal to the most probable speed of gas Y at 60 K. The molecular weight of the gas Y is

40. The total number of α and β particles emitted in the nuclear reaction $^{238}_{92}U \rightarrow {}^{214}_{82}Pb$ is

41. The oxidation number of Mn in the product of alkaline oxidative fusion of MnO_2 is

42. The coordination number of Al in the crystalline state of $AlCl_3$ is

43. The number of water molecule(s) directly bonded to the metal centre in $CuSO_4 \cdot 5H_2O$ is

44. In a constant-volume calorimeter, 3.5 g of a gas with molecular weight 28 was burnt in excess oxygen at 298.0 K. The temperature of the calorimeter was found to increase from 298.0 K to 298.45 K due to the combustion process. Given that the heat capacity of the calorimeter is 2.5 kJ K^{-1}, the numerical value for the enthalpy of combustion of the gas in kJ mol^{-1} is

45. The total number of cyclic structures as well as stereoisomers possible for a compound with the molecular formula C_5H_{10} is

Answers

1. d	**2.** d	**3.** b	**4.** d	**5.** a
6. c	**7.** a	**8.** b	**9.** a	**10.** b
11. b	**12.** b	**13.** c	**14.** b	**15.** b
16. a, b	**17.** b, c	**18.** c, d	**19.** a, d	**20.** a, b, c
21. a, d	**22.** a, b, d	**23.** a, d	**24.** a, b, c	**25.** b, c
26. b, d	**27.** c			

28.

	p	q	r	s	t
A	**p**	q	r	**s**	t
B	p	**q**	r	**s**	t
C	p	q	**r**	s	**t**
D	p	**q**	r	s	**t**

29.

	p	q	r	s	t
A	**p**	**q**	r	s	t
B	**p**	q	r	**s**	**t**
C	p	q	**r**	**s**	t
D	**p**	q	r	s	t

30.

	p	q	r	s	t
A	**p**	q	**r**	s	**t**
B	p	q	r	**s**	**t**
C	**p**	**q**	r	s	t
D	**p**	**q**	r	**s**	t

31.

	p	q	r	s	t
A	**p**	**q**	r	**s**	**t**
B	p	q	r	**s**	**t**
C	**p**	q	r	s	t
D	p	q	**r**	s	t

32. d **33.** c **34.** b **35.** b **36.** a **37.** b

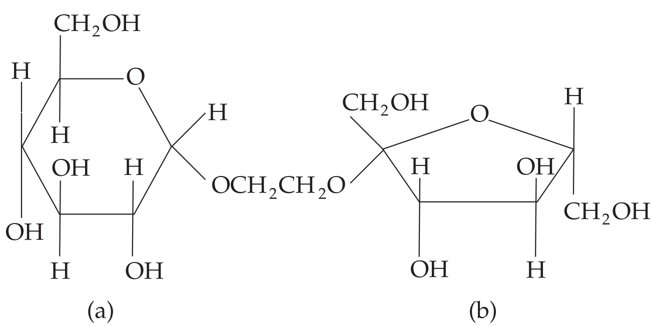
38	39	40	41	42	43	44	45
0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3
4	**4**	4	4	4	**4**	4	4
5	5	5	5	5	5	5	5
6	6	6	**6**	**6**	6	6	6
7	7	7	7	7	7	7	**7**
8	8	**8**	8	8	8	8	8
9	9	9	9	9	9	**9**	9

❑

9

IIT Questions—6

1. The correct statement about the following disaccharide is



(a) Ring (a) is pyranose with α - glycosidic link
(b) Ring (a) is furanose with α - glycosidic link
(c) Ring (b) is furanose with α - glycosidic link
(d) Ring (b) is pyranose with β - glycosidic link

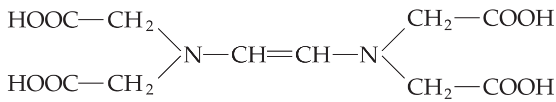
2. The synthesis of 3-octyne is achieved by adding a bromoalkane into a mixture of sodium amide and an alkyne. The bromoalkane and alkyne respectively are

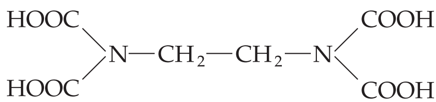
(a) $BrCH_2CH_2CH_2CH_2CH_3$ and $CH_3CH_2C \equiv CH$
(b) $BrCH_2CH_2CH_3$ and $CH_3CH_2CH_2C \equiv CH$
(c) $BrCH_2CH_2CH_2CH_2CH_3$ and $CH_3C \equiv CH$
(d) $BrCH_2CH_2CH_2CH_3$ and $CH_3CH_2C \equiv CH$

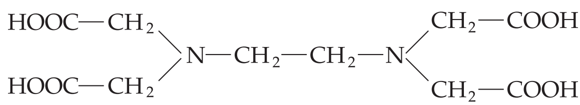
3. The ionization isomer of $[Cr(H_2O)_4Cl(NO_2)]Cl$ is

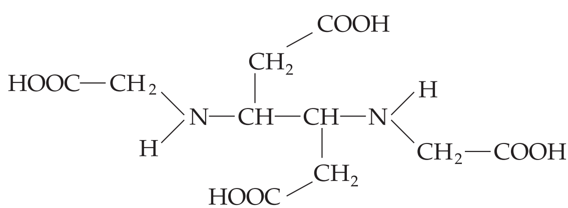
(a) $[Cr(H_2O)_4(O_2N)]Cl_2$ (b) $[Cr(H_2O)_4Cl_2](NO_2)$
(c) $[Cr(H_2O)_4Cl(ONO)]Cl$ (d) $[Cr(H_2O)_4Cl_2(NO_2)] \cdot H_2O$

4. The correct structure of ethylenediaminetetraacetic acid (EDTA) is

(a) 

(b) 

(c) 

(d) 

5. The bond energy (in **kcal mol^{-1}**) of a C—C single bond is approximately

(a) 1 (b) 10

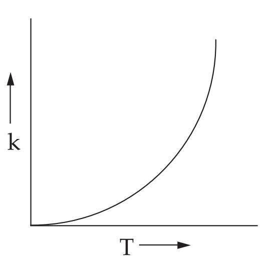
(c) 100 (d) 1000

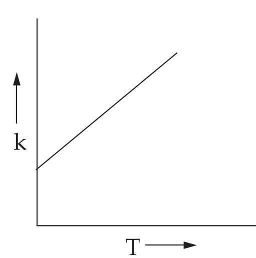
6. The species which by definition has **ZERO** standard molar enthalpy of formation at 298 K is

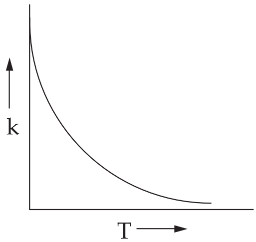
(a) Br_2 (g) (b) Cl_2 (g)

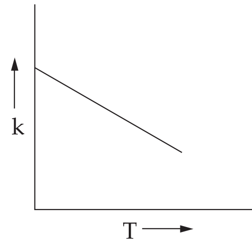
(c) H_2O (g) (d) CH_4 (g)

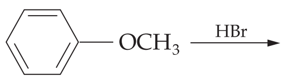
7. Plots showing the variation of the rate constant (k) with temperature (T) are given below. The plot that follows Arrhenius equation is

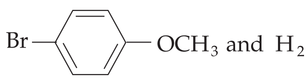
(a) 

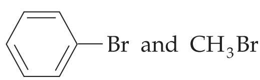
(b) 

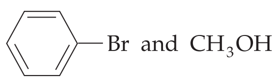
(c) 

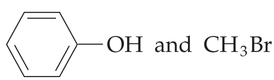
(d) 

8. In the reaction  the products are

(a) 

(b) 

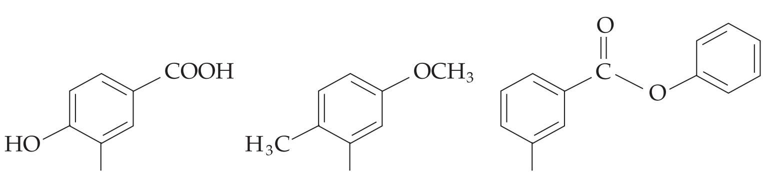
(c) 

(d) 

9. The species having pyramidal shape is

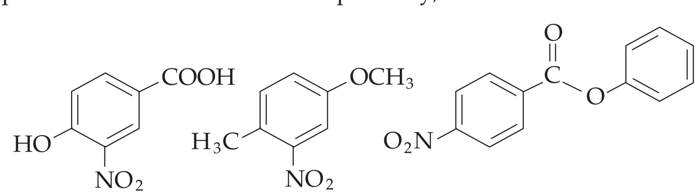
(a) SO_3 (b) BrF_3 (c) SiO_3^{2-} (d) OSF_2

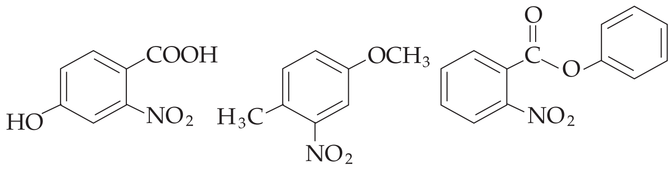
10. The compounds P, Q and S

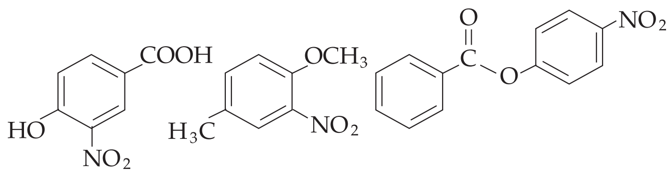


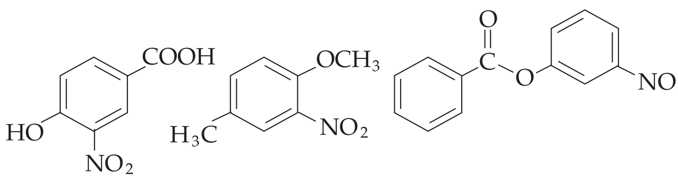
P Q S

were separately subjected to nitration using HNO_3/H_2SO_4 mixture. The major product formed in each case respectively, is

(a) 

(b) 

(c) 

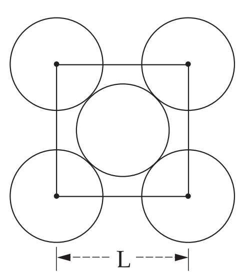
(d) 

11. Assuming that Hund's rule is violated, the bond order and magnetic nature of the diatomic molecule B_2 is

(a) 1 and diamagnetic (b) 0 and diamagnetic

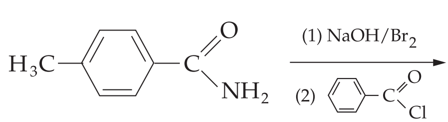
(c) 1 and paramagnetic (d) 0 and paramagnetic

12. The packing efficiency of the two-dimensional square unit cell shown below is

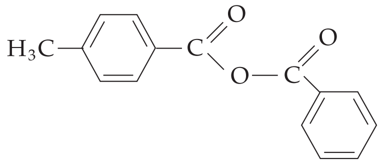


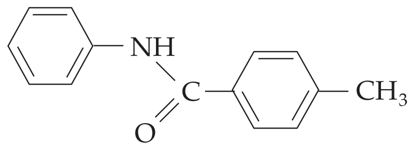
(a) 39.27% (b) 68.02%

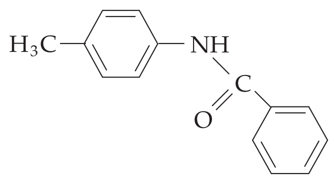
(c) 74.05% (d) 78.54%

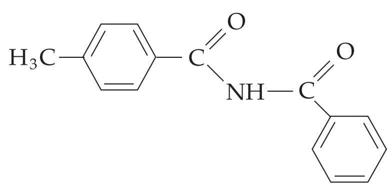
13. In the reaction 

T the structure of the product T is

(a) 

(b) 

(c) 

(d) 

14. The complex showing a spin-only magnetic moment of 2.82 BM, is

(a) $Ni(CO)_4$ (b) $[NiCl_4]^{2-}$

(c) $Ni(PPh_3)_4$ (d) $Ni(CN)_4]^{2-}$

15. Among the following, the intensive property is (properties are)

(a) molar conductivity (b) electromotive force

(c) resistance (d) heat capacity

16. The reagent(s) used for softening the temporary hardness of water is(are)

(a) $Ca_3(PO_4)_2$ (b) $Ca(OH)_2$

(c) Na_2CO_3 (d) NaOCl

17. Aqueous solutions of HNO_3, KOH, CH_3COOH, and CH_3COONa of identical concentrations are provided. The pair(s) of solutions which form a buffer upon mixing is(are)

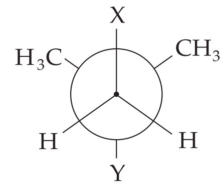
(a) HNO_3 and CH_3COOH

(b) KOH and CH_3COONa

(c) HNO_3 and CH_3COONa

(d) CH_3COOH and CH_3COONa

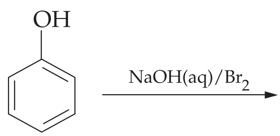
18. In the Newman projection for 2, 2-dimethylbutane

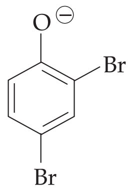


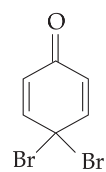
X and **Y** can respectively be

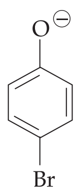
(a) H and H (b) H and C_2H_5

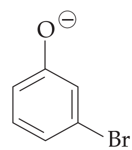
(c) C_2H_5 and H (d) CH_3 and CH_3

19. In the reaction  the intermediate(s) is(are)

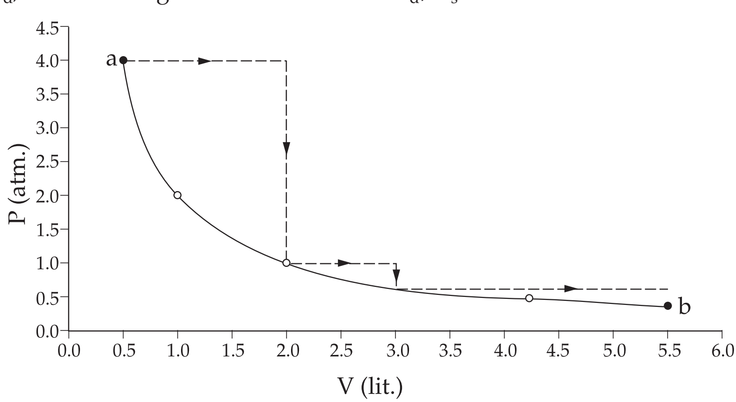
(a) 

(b) 

(c) 

(d) 

20. One mole of an ideal gas is taken from **a** to **b** along two paths denoted by the solid and the dashed lines as shown in the graph below. If the work done along the solid line path is w_s and that along the dotted line path is w_d, then the integer closest to the ratio w_d/w_s is



21. Among the following, the number of elements showing only one nonzero oxidation state is

O, Cl, F, N, P, Sn, Tl, Na, Ti

22. Silver (atomic weight = 108 g mol^{-1}) has a density of 10.5 g cm^{-3}. The number of silver atoms on a surface of area 10^{-12}m^2 can be expressed in scientific notation as $y \times 10^x$. The value of x is

23. The total number of diprotic acids among the following is

H_3PO_4 H_2SO_4 H_3PO_3 H_2CO_3 $H_2S_2O_7$
H_3BO_3 H_3PO_2 H_2CrO_4 H_2SO_3

24. Total number of geometrical isomers for the complex $[RhCl(CO)(PPh_3)(NH_3)]$ is

Paragraph Type Questions

This Section contains **2 paragraphs.** Based upon the first paragraph **3 multiple choice questions** and based upon the second paragraph **2 multiple choice questions** have to be answered. Each of these questions has four choices (a), (b), (c) and (d) out of which **ONLY ONE** is correct.

Paragraph for Questions 25 to 27

Copper is the most noble of the first row transition metals and occurs in small deposits in several countries. Ores of copper include chalcanthite ($CuSO_4{\cdot}5H_2O$), atacamite [$Cu_2Cl(OH)_3$], cuprite (Cu_2O), copper glance (Cu_2S) and malachite [$CU_2(OH)_2CO_3$]. However, 80% of the world copper production comes from the ore chalcopyrite ($CuFeS_2$). The extraction of copper from chalcopyrite involves partial roasting, removal of iron and self-reduction.

25. Partial roasting of chalcopyrite produces

(a) Cu_2S and FeO (b) Cu_2O and FeO
(c) CuS and Fe_2O_3 (d) Cu_2O and Fe_2O_3

26. Iron is removed from chalcopyrite is

(a) FeO (b) FeS
(c) Fe_2O_3 (d) $FeSiO_3$

27. In self-reduction, the reducing species is

(a) S (b) O^{2-}
(c) S^{2-} (d) SO_2

Paragraph for Questions 28 to 29

The concentration of potassium ions inside a biologial cell is at least twenty times higher than the outside. The resulting potential difference across the cell is important in several processes such as transmission of nerve impulses and maintaining the ion balance. A simple model for such a concentration cell involving a metal M is

$$M(s) \mid M^{+} (aq; 0.05 \text{ molar}) \parallel M^{+} (aq; 1 \text{ molar}) \mid M(s)$$

For the above electrolytic cell the magnitude of the cell potential $|E_{cell}| = 70$ mV.

28. For the above cell

(a) $E_{cell} < 0; \Delta G > 0$ (b) $E_{cell} > 0; \Delta G < 0$

(c) $E_{cell} < 0; \Delta G^\circ > 0$ (d) $E_{cell} > 0; \Delta G^\circ < 0$

29. If the 0.05 molar solution of M^+ is replaced by a 0.0025 molar M^+ solution, then the magnitude of the cell potential would be

(a) 35 mV (b) 70 mV

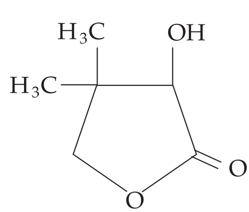
(c) 140 mV (d) 700 mV

Paragraph Type Questions

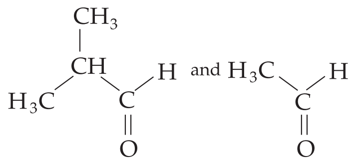
This Section contains **2 paragraphs.** Based upon each of the paragraph **3 multiple choice questions** have to be answered. Each of these questions has four choices (a), (b), (c) and (d) out of which **ONLY ONE** is correct.

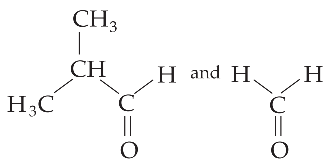
Paragraph for Questions 30 to 32

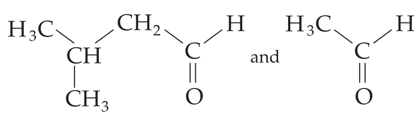
Two aliphatic aldehydes P and Q react in the presence of aqueous K_2CO_3 to give compound R, which upon treatment with HCN provides compound S. On acidification and heating, S gives the product shown below:

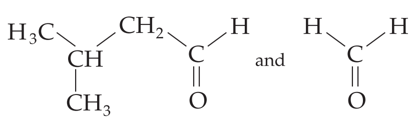


30. The compounds P and Q respectively are

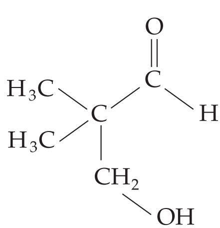
(a) 

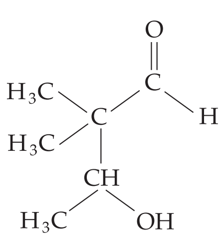
(b) 

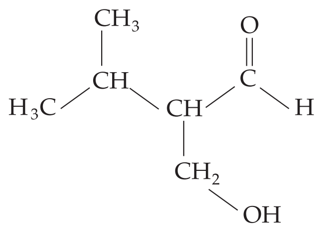
(c) 

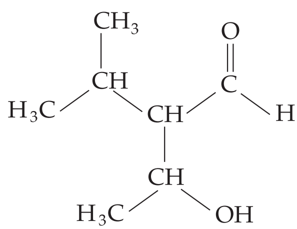
(d) 

31. The compound R is

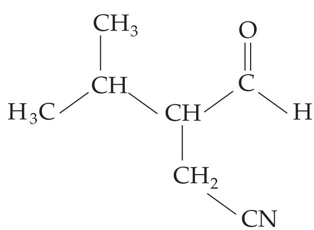
(a) 

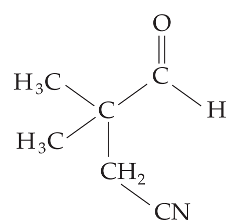
(b) 

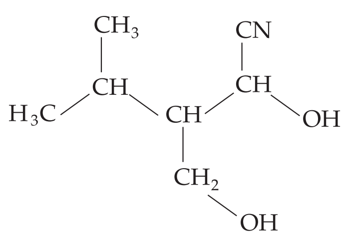
(c) 

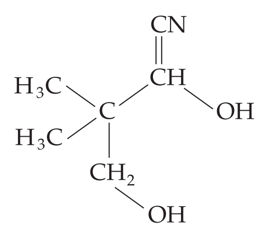
(d) 

32. The compound S is

(a) 

(b) 

(c) 

(d) 

Paragraph for Questions 33 to 35

The hydrogen-like species Li^{2+} is in a spherically symmetric state S_1 with one radial node. Upon absorbing light the ion undergoes transition to a state S_2. The state S_2 has one radial node and its energy is equal to the ground state energy of the hydrogen atom.

33. The State S_1 is

(a) 1s (b) 2s

(c) 2p (d) 3s

34. Energy of the state S_1 in units of the hydrogen atom ground state energy is

(a) 0.75 (b) 1.50

(c) 2.25 (d) 4.50

35. The orbital angular momentum quantum number of the state S_2 is

(a) 0 (b) 1

(c) 2 (d) 3

Integer Type Questions

This Section contains **TEN** questions. The answer to each question is a **single digit integer** ranging from 0 to 9. The correct digit below the question number in the ORS is to be bubbled.

36. Amongst the following, the total number of compounds whose aqueous solution turns red litmus paper blue is

KCN K_2SO_4 $(NH_4)_2C_2O_4$ $NaCl$ $Zn(NO_3)_2$

$FeCl_3$ K_2CO_3 NH_4NO_3 $LiCN$

37. Based on VSEPR theory, the number of 90 degree F—Br—F angles in BrF_5 is

38. The value of n in the molecular formula $Be_nAl_2Si_6O_{18}$ is

39. A student performs a titration with different burettes and finds titre values of 25.2 mL, 25.25 mL, and 25.0 mL. The number of significant figures in the average titre value is

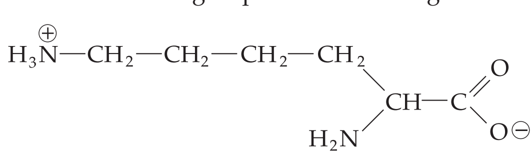
40. The concentration of R in the reaction $R \rightarrow P$ was measured as a function of time and the following data is obtained

[R] (molar)	1.0	0.75	0.40	0.10
t(min.)	0.0	0.05	0.12	0.18

The order of the reaction is

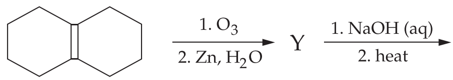
41. The number of neutrons emitted when ${}^{235}_{92}U$ undergoes controlled nuclear fission to ${}^{142}_{54}Xe$ and ${}^{90}_{38}Sr$ is

42. The total number of basic groups in the following form of lysine is

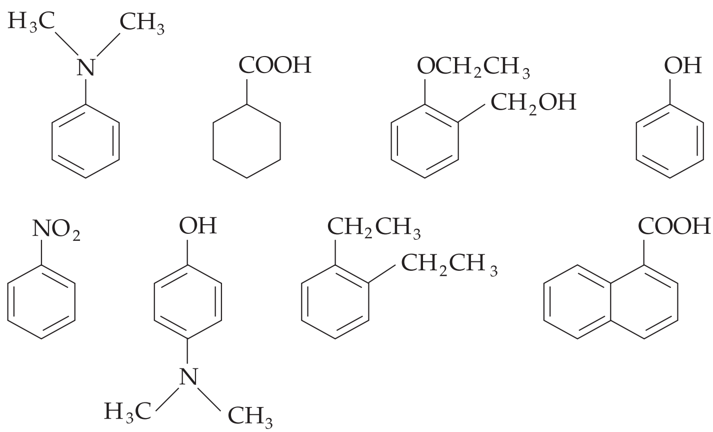


43. The total number of cyclic isomers possible for a hydrocarbon with the molecular formula C_4H_6 is

44. In the scheme given below, the total number of intramolecular aldol condensation products formed from **'Y'** is



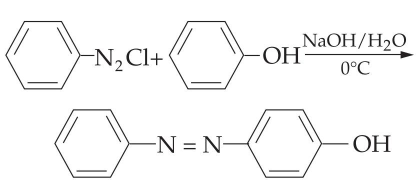
45. Amongst the following, the total number of compounds soluble in aqueous NaOH is

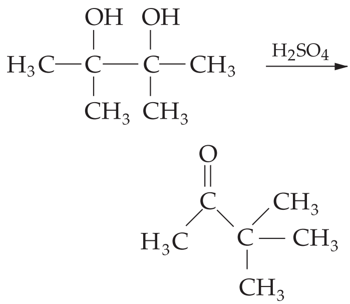


Matrix Type Questions

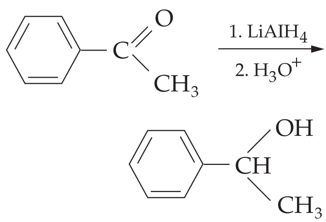
This section contains **2 questions.** Each question has four statements (a, b, c and d) given in **Column I** and five statements (p, q, r, s and t) in **Column II.** Any given statement in **Column I** can have correct matching with one or more statements given in **Column II.** For example, if for a given question, statement b matches with the statements given in q and r, then for that particular question, against statement b, darken the bubbles corresponding to q and r in the ORS.

46. Match the reactions in **Column I** with appropriate options in **Column II**.

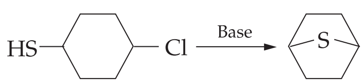
Column I	**Column II**
(a) 	(p) Racemic mixture

(b) 

(q) Addition reaction

(c) 

(r) Substitution reaction

(d) 

(s) Coupling reaction

(t) Carbocation intermediate

47. All the compounds listed in **Column I** react with water. Match the result of the respective reactions with the appropriate options listed in **Column II.**

Column I	Column II
(a) $(CH_3)_2SiCl_2$	(p) Hydrogen halide formation
(b) XeF_4	(q) Redox reaction
(c) Cl_2	(r) Reacts with glass
(d) VCl_5	(s) polymerization
	(t) O_2 formation

Answers

1. a	**2.** d	**3.** b	**4.** c	**5.** c
6. b	**7.** a	**8.** d	**9.** d	**10.** c
11. a	**12.** d	**13.** c	**14.** b	**15.** a, b
16. b, c	**17.** d	**18.** b, d	**19.** a, b, c	

20	21	22	23	24
0	0	0	0	0
1	1	1	1	1
2	**2**	2	2	2
3	3	3	3	**3**
4	4	4	4	4
5	5	5	5	5
6	6	6	**6**	6
7	7	**7**	7	7
8	8	8	8	8
9	9	9	9	9

25. a **26.** d **27.** c **28.** b **29.** c
30. b **31.** a **32.** d **33.** b **34.** c
35. b

36	37	38	39	40	41	42	43	44	45
0	**0**	0	0	**0**	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	**2**	2	2	2
3	3	**3**	**3**	3	**3**	3	3	**3**	3
4	4	4	4	4	4	4	4	4	**4**
5	5	5	5	5	5	5	**5**	5	5
6	6	6	**6**	6	6	6	6	6	6
7	7	7	7	7	7	7	7	7	7
8	8	8	8	8	8	8	8	8	8
9	9	9	9	9	9	9	9	9	9

46.

	p	q	r	s	t
a	p	q	r	s	t
b	p	q	r	s	t
c	p	q	r	s	t
d	p	q	r	s	t

a →r, s

b →t

c →p, q

d →r

47.

	p	q	r	s	t
a	p	q	r	s	t
b	p	q	r	s	t
c	p	q	r	s	t
d	p	q	r	s	t

a →p, s

b →p, q, r, t

c →p, q

d →p

❑

10

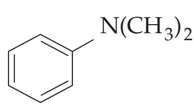
IIT Questions—7

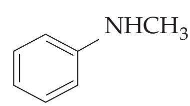
1. The freezing point (in °C) of a solution containing 0.1 g of $K_3[Fe(CN)_6]$ (mol. wt. 329) in 100 g of water ($K_f = 1.86$ K kg mol^{-1}) is

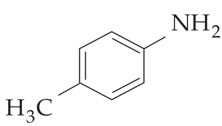
(a) -2.3×10^{-2} (b) -5.7×10^{-2}

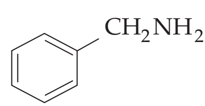
(c) -5.7×10^{-3} (d) -1.2×10^{-2}

2. Amongst the compounds given, the one that would form a brilliant colored dye on treatment with $NaNO_2$ in dil. HCl followed by addition to an alkaline solution of β-naphthol is

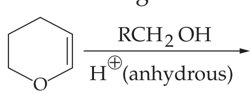
(a) 

(b) 

(c) 

(d) 

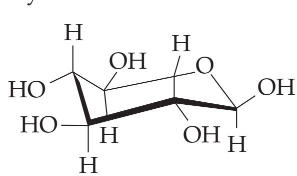
3. The major product of the following reaction is



(a) a hemiacetal (b) an acetal

(c) an ether (d) an ester

4. The following carbohydrate is



(a) a ketohexose (b) an aldohexose
(c) an α-furanose (d) an α-pyranose

5. Oxidation states of the metal in the minerals haematite and magnetite, respectively, are
(a) II, III in haematite and III in magnetite
(b) II, III in haematite and II in magnetite
(c) II in haematite and II, III in magnetite
(d) III in haematite and II, III in magnetite

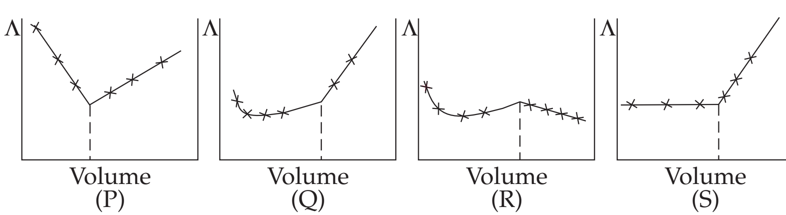
6. Among the following complexes (**K–P**)
$K_3[Fe(CN)_6]$ (**K**), $[Co(NH_3)_6]Cl_3$ (**L**), $Na_3[Co(oxalate)_3]$ (**M**),
$[Ni(H_2O)_6]Cl_2$ (**N**), $K_2[Pt(CN)_4]$ (**O**) and $[Zn(H_2O)_6](NO_3)_2$ (**P**)
the diamagnetic compounds are
(a) **K, L, M, N** (b) **K, M, O, P**
(c) **L, M, O, P** (d) **L, M, N, O**

7. Passing H_2S gas into a mixture of Mn^{2+}, Ni^{2+}, Cu^{2+} and Hg^{2+} ions in an acidified aqueous solution precipitates
(a) CuS and HgS (b) MnS and CuS
(c) MnS and NiS (d) NiS and HgS

8. Consider the following cell reaction:
$$2Fe(s) + O_2(g) + 4H^+(aq) \rightarrow 2Fe^{2+}(aq) + 2H_2O(l) \quad E° = 1.67 \text{ V}$$
Given $[Fe^{2+}] = 10^{-3}$ M, $p_{O_2} = 0.1$ atm and pH = 3, the cell potential at 25°C is
(a) 1.47 V (b) 1.77 V (c) 1.87 V (d) 1.57 V

9. Dissolving 120 g of urea (mol. wt. 60) in 1000 g of water gave a solution of density 1.15 g/mL. The molarity of the solution is
(a) 1.78 M (b) 2.00 M (c) 2.05 M (d) 2.22 M

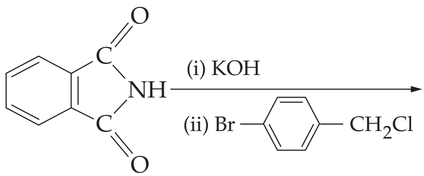
10. $AgNO_3$ (aq) was added to an aqueous KCl solution gradually and the conductivity of the solution was measured. The plot of conductance Λ versus the volume of $AgNO_3$ is

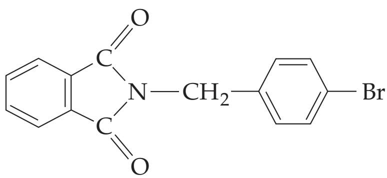


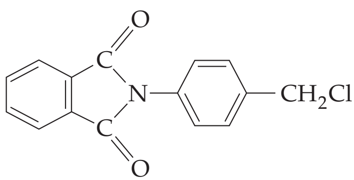
(a) (P) (b) (Q) (c) (R) (d) (S)

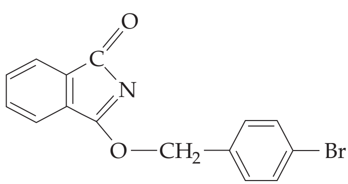
11. Among the following compounds, the most acidic is
(a) *p*-nitrophenol (b) *p*-hydroxybenzoic acid
(c) *o*-hydroxybenzoic acid (d) *p*-toluic acid

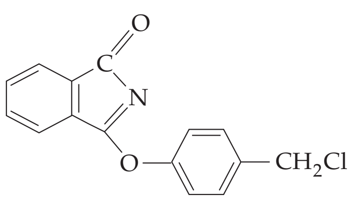
12. The major product of the following reaction is



(a) 

(b) 

(c) 

(d) 

13. Extra pure N_2 can be obtained by heating

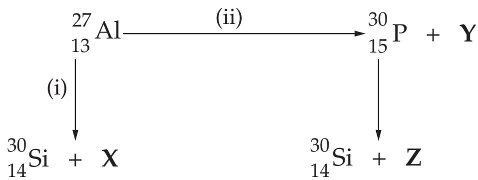
(a) NH_3 with CuO (b) NH_4NO_3

(c) $(NH_4)_2Cr_2O_7$ (d) $Ba(N_3)_2$

14. Geometrical shapes of the complexes formed by the reaction of Ni^{2+} with Cl^-, CN^- and H_2O, respectively, are

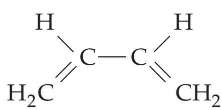
(a) octahedral, tetrahedral and square planar
(b) tetrahedral, square planar and octahedral
(c) square planar, tetrahedral and octahedral
(d) octahedral, square planar and octahedral

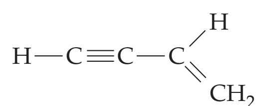
15. Bombardment of aluminium by α-particle leads to its artificial disintegration in two ways, (i) and (ii) as shown. Products **X, Y** and **Z** respectively are



(a) proton, neutron, positron (b) neutron, positron, proton
(c) proton, positron, neutron (d) positron, proton, neutron

16. Amongst the given options, the compound(s) in which all the atoms are in one plane in all the possible conformations (if any), is (are)

(a) 

(b) 

(c) $H_2C{=}C{=}O$

(d) $H_2C{=}C{=}CH_2$

17. According to kinetic theory of gases

(a) collisions are always elastic
(b) heavier molecules transfer more momentum to the wall of the container
(c) only a small number of molecules have very high velocity
(d) between collisions, the molecules move in straight lines with constant velocities

18. The correct statement(s) pertaining to the adsorption of a gas on a solid surface is (are)

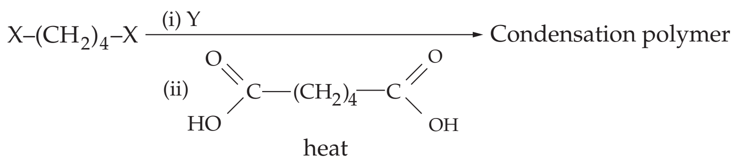
(a) adsorption is always exothermic
(b) physisorption may transform into chemisorption at high temperature
(c) physisorption increases with increasing temperature but chemisorption decreases with increasing temperature
(d) chemisorption is more exothermic than physisorption, however it is very slow due to higher energy of activation

19. Extraction of metal from the ore cassiterite involves

(a) carbon reduction of an oxide ore
(b) self-reduction of a sulphide ore
(c) removal of copper impurity
(d) removal of iron impurity

20. Reduction of the metal centre in aqueous permanganate ion involves
(a) 3 electrons in neutral medium
(b) 5 electrons in neutral medium
(c) 3 electrons in alkaline medium
(d) 5 electrons in acidic medium

21. The correct functional group X and the reagent/reaction conditons Y in the following scheme are



(a) $X = COOCH_3$, $Y = H_2/Ni/heat$
(b) $X = CONH_2$, $Y = H_2/Ni/heat$
(c) $X = CONH_2$, $Y = Br_2/NaOH$
(d) $X = CN$, $Y = H_2/Ni/heat$

22. For the first order reaction $2N_2O_5(g) \rightarrow 4NO_2\,(g) + O_2\,(g)$
(a) the concentration of the reactant decreases exponentially with time
(b) the half-life of the reaction decreases with increasing temperature
(c) the half-life of the reaction depends on the initial concentration of reactant
(d) the reaction proceeds to 99.6% completion in eight half-life duration

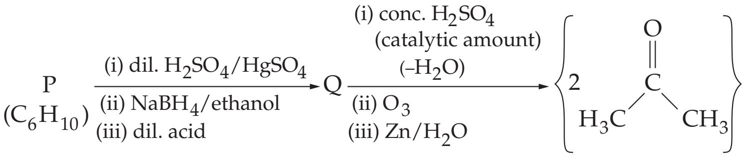
23. The equilibrium $2Cu^{I} \rightleftharpoons Cu^{0} + Cu^{II}$ in aqueous medium at 25°C shifts towards the left in the presence of
(a) NO_3^- (b) Cl^- (c) SCN^- (d) CN^-

Paragraph-Type Questions

This section contains **2 paragraphs.** Based upon the first paragraph **2 multiple choice questions** and based upon the second paragraph **3 multiple choice questions** have to be answered. Each of these questions has four choices (a), (b), (c) and (d) out of which **ONLY ONE** is correct.

Paragraph for Questions 24 and 25

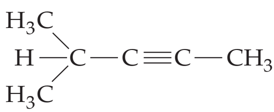
An acyclic hydrocarbon P, having molecular formula C_6H_{10}, gave acetone as the only organic product through the following sequence of reactions, in which Q is an intermediate organic compound.

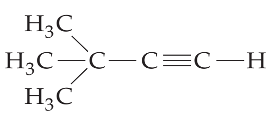


24. The structure of compound P is

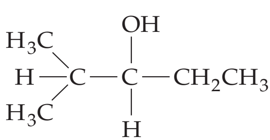
(a) $CH_3CH_2CH_2CH_2—C≡C—H$

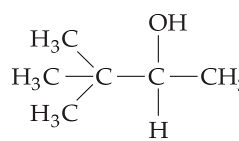
(b) $H_3CH_2C—C≡C—CH_2CH_3$

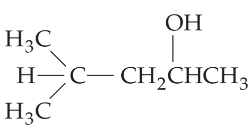
(c) 

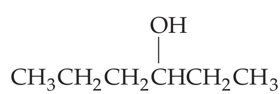
(d) 

25. The structure of compound Q is

(a) 

(b) 

(c) 

(d) 

Paragraph for Questions 26 to 28

When a metal rod M is dipped into an aqueous colourless concentrated solution of compound N, the solution turns light blue. Addition of aqueous NaCl to the blue solution gives a white precipitate O. Addition of aqueous NH_3 dissolves O and gives an intense blue solution.

26. The metal rod M is

(a) Fe (b) Cu (c) Ni (d) Co

27. The compound N is

(a) $AgNO_3$ (b) $Zn(NO_3)_2$ (c) $Al(NO_3)_3$ (d) $Pb(NO_3)_2$

28. The final solution contains

(a) $[Pb(NH_3)_4]^{2+}$ and $[CoCl_4]^{2-}$ (b) $[Al(NH_3)_4]^{3+}$ and $[Cu(NH_3)_4]^{2+}$

(c) $[Ag(NH_3)_2]^+$ and $[Cu(NH_3)_4]^{2+}$ (d) $[Ag(NH_3)_2]^+$ and $[Ni(NH_3)_6]^{2+}$

Integer-Answer-Type Questions

The answer to each question is a **single digit integer** ranging from 0 to 9. The bubble corresponding to the correct answer is to be darkened in the ORS.

29. The work function (ϕ) of some metals is listed below. The number of metals which will show photoelectric effect when light of 300 nm wavelength falls on the metal is

Metal	Li	Na	K	Mg	Cu	Ag	Fe	Pt	W
ϕ (eV)	2.4	2.3	2.2	3.7	4.8	4.3	4.7	6.3	4.75

30. To an evacuated vessel with movable piston under external pressure of 1 atm., 0.1 mol of He and 1.0 mol of an unknown compound (vapour pressure 0.68 atm. at 0°C) are introduced. Considering the ideal gas behaviour, the total volume (in litre) of the gases at 0°C is close to

31. Reaction of Br_2 with Na_2CO_3 in aqueous solution gives sodium bromide and sodium bromate with evolution of CO_2 gas. The number of sodium bromide molecules involved in the balanced chemical equation is

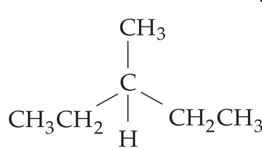
32. The difference in the oxidation numbers of the two types of sulphur atoms in $Na_2S_4O_6$ is

33. A decapeptide (mol. wt. 796) on complete hydrolysis gives glycine (mol. wt. 75), alanine and phenylalanine. Glycine contributes 47.0% to the total weight of the hydrolysed products. The number of glycine units present in the decapeptide is

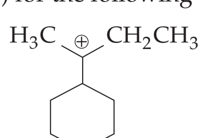
34. The total number of alkenes possible by dehydrobromination of 3-bromo-3-cyclopentylhexane using alcoholic KOH is

35. The maximum number of electrons that can have principal quantum number, $n = 3$, and spin quantum number, $m_S = -1/2$, is

36. The maximum number of isomers (including stereoisomers) that are possible on monochlorination of the following compound is



37. The total number of contributing structure showing hyperconjugation (involving C—H bonds) for the following carbocation is



38. Among the following, the number of compounds that can react with PCl_5 to give $POCl_3$ is O_2, CO_2, SO_2, H_2O, H_2SO_4, P_4O_{10}

39. The volume (in mL) of 0.1 M $AgNO_3$ required for complete precipitation of chloride ions present in 30 mL of 0.01 M solution of $[Cr(H_2O)_5Cl]Cl_2$, as silver chloride is close to

40. In 1 L saturated solution of AgCl $[K_{sp}(AgCl) = 1.6 \times 10^{-10}]$, 0.1 mol of CuCl $[K_{sp}(CuCl) = 1.0 \times 10^{-6}]$, is added. The resultant concentration of Ag^+ in the solution is 1.6×10^{-x}. The value of "x" is

41. The number of hexagonal faces that are present in a truncated octahedron is

Matrix-Matching-Type Questions

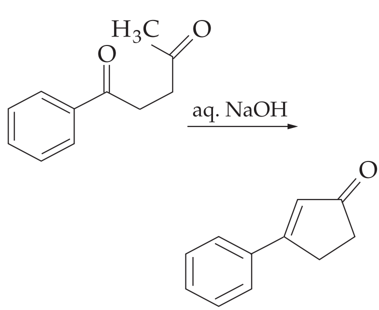
This section contains **2 questions.** Each question has four statements (a, b, c and d) given in **Column I** and five **statements** (p, q, r, s and t) in **Column II.** Any given statement in **Column I** can have correct matching with **one or more** statement(s) given in **Column II.** For example, if for a given question, statement b matches with the statements given in q and r, then for the particular question, against statement b, darken the bubbles corresponding to q and r in the ORS.

42. Match the transformations in **Column I** with appropriate options in **Column II**.

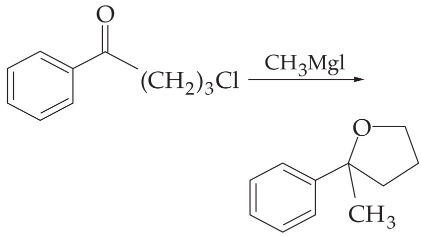
Column I	**Column II**
(a) $CO_2(s) \rightarrow CO_2(g)$	(p) phase transition
(b) $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$	(q) allotropic change
(c) $2H\bullet \rightarrow H_2(g)$	(r) ΔH is positive
(d) $P_{(\text{white, solid})} \rightarrow P_{(\text{red, solid})}$	(s) ΔS is positive
	(t) ΔS is negative

43. Match the reaction in **Column I** with appropriate types of steps/reactive intermediate involved in these reactions as given in **Column II.**

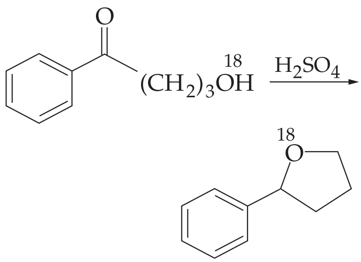
Column I **Column II**

(a) 

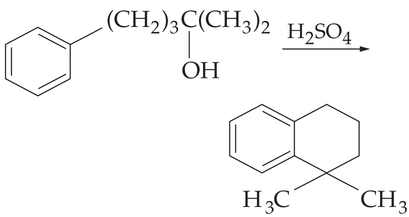
(p) Nucleophilic substitution

(b) 

(q) Electrophilic substitution

(c) 

(r) Dehydration

(d) 

(s) Nucleophilic addition

(t) Carbanion

Answers

1. a **2.** c **3.** c **4.** b **5.** d
6. c **7.** a **8.** d **9.** c **10.** d
11. c **12.** a **13.** d **14.** b **15.** a
16. b, c **17.** a, b, c, d **18.** a, b, d **19.** a, c, d **20.** a, d
21. a, b, c, d **22.** a, b, d **23.** b, c, d **24.** d **25.** b
26. b **27.** a **28.** c

	29	30	31	32	33	34	35	36	37	38	39	40	41
0	○	○	○	○	○	○	○	○	○	○	○	○	○
1	○	○	○	○	○	○	○	○	○	○	○	○	○
2	○	○	○	○	○	○	○	○	○	○	○	○	○
3	○	○	○	○	○	○	○	○	○	○	○	○	○
4	●	○	○	○	○	○	○	○	○	○	○	○	○
5	○	○	●	●	○	●	○	○	○	●	○	○	○
6	○	○	○	○	●	○	○	○	●	○	●	○	○
7	○	●	○	○	○	○	○	○	○	○	○	●	○
8	○	○	○	○	○	○	○	●	○	○	○	○	●
9	○	○	○	○	○	○	●	○	○	○	○	○	○

42.

	p	q	r	s	t
a	●	○	●	●	○
b	○	○	●	●	○
c	○	○	○	○	●
d	●	●	○	○	●

43.

	p	q	r	s	t
a	○	○	●	●	●
b	●	○	○	●	○
c	○	○	●	●	○
d	○	●	●	○	○

❑