CHAPTER

9

Solid State

EXERCISE I (JEE MAIN)

Basics

1. Most crystals that show good cleavage because their atoms, ions or molecules are

(a) weakly bonded together
(b) strongly bonded together
(c) spherically symmetrical
(d) arranged in planes

2. Which of the following is the only incorrect statement regarding amorphous solids?

(a) On heating, they may become crystalline at some temperature.
(b) They may become crystalline on keeping for long time.
(c) Amorphous solids can be moulded by heating.
(d) They are anisotropic in nature.

3. A solid melt slightly above 273 K and is a poor conductor of heat and electricity. To which of the following categories does it belong?

(a) Ionic solid
(b) Covalent solid
(c) Metallic solid
(d) Molecular solid

4. A solid is soft, good conductor of electricity and has very high melting point. Its one of the allotropic forms is the hardest known substance. Hence, the solid is an example of

(a) Ionic solid
(b) Covalent solid
(c) Molecular solid
(d) Metallic solid

5. Constituent particles in quartz are bonded by

(a) Electrovalent bonds
(b) Covalent bonds
(c) Van der Waal's forces
(d) Metallic bonds

6. Ionic solids are characterized by

(a) Good conductivity in solid state
(b) High vapour pressure
(c) Low melting point
(d) Solubility in polar solvents

7. Which of the following is an example of metallic crystal solid?

(a) C (b) Si
(c) W (d) AgCl

8. Which of the following is an example of covalent crystal solid?

(a) SiO_2
(b) Al
(c) Ar
(d) NaF

9. The particles would be stationary in a lattice only at

(a) 0°C
(b) 0 K
(c) 298 K
(d) 273 K

10. Iodine molecules are held in the crystal lattice by

(a) London forces
(b) Dipole–dipole interactions
(c) Covalent bonds
(d) Ionic bonds

11. The unit cell of highest symmetry is

(a) cubic
(b) triclinic
(c) hexagonal
(d) monoclinic

12. The unit cell of lowest symmetry is

(a) cubic
(b) triclinic
(c) hexagonal
(d) monoclinic

13. A match box exhibits _______ geometry.

(a) cubic
(b) orthorhombic
(c) triclinic
(d) monoclinic

14. If the three inter-axial angles defining the unit cell are all equal in magnitude, the crystal cannot belong to the ____ system.

(a) orthorhombic
(b) hexagonal
(c) tetragonal
(d) cubic

15. In a crystal, the atoms are located at the position of

(a) zero potential energy
(b) infinite potential energy
(c) minimum potential energy
(d) maximum potential energy

16. A lattice is defined as

(a) the amount of energy required, per mole, to separate the ions from their lattice positions to an infinite distance in the gas phase
(b) the distance separating the cations and anions
(c) a set of all points with identical environments within the crystal
(d) the arrangement of electrons in various energy levels

17. The axial angles in triclinic crystal system are

(a) $\alpha = \beta = \gamma = 90°$
(b) $\alpha = \gamma = 90°, \beta \neq 90°$
(c) $\alpha \neq \beta \neq \gamma \neq 90°$
(d) $\alpha = \beta = \gamma \neq 90°$

18. TiO_2 is a well-known example of

(a) Triclinic system
(b) Tetragonal system
(c) Monoclinic system
(d) Cubic system

19. In a tetragonal crystal

(a) $\alpha = \beta = 90° \neq \gamma$; $a = b = c$
(b) $\alpha = \beta = \gamma = 90°$; $a = b \neq c$
(c) $\alpha = \beta = \gamma = 90°$; $a \neq b \neq c$
(d) $\alpha = \beta = 90°$; $\gamma = 120°$; $a = b \neq c$

20. Which of the following crystalline arrangement will have at least one of the angles equals to 90^o and at least two axial lengths equal?

(a) Orthorhombic
(b) Rhombohedral
(c) Monoclinic
(d) Tetragonal

Analysis of Cubic Crystals

21. An element occurring in the body-centred cubic (BCC) structure has 1.208×10^{23} unit cells. The total number of atoms of the element in these cells will be

(a) 2.416×10^{23}
(b) 3.618×10^{23}
(c) 6.04×10^{22}
(d) 1.208×10^{23}

22. The rank of a cubic unit cell is 4. The type of cell as

(a) Body-centred
(b) Face-centred
(c) Primitive
(d) End-centred

23. An alloy of copper, silver and gold is found to have copper constituting the face-centred cubic (FCC) lattice. If silver atoms occupy the edge centres and gold is present at body centre, the alloy has a formula

(a) Cu_4Ag_2Au
(b) Cu_4Ag_4Au
(c) Cu_4Ag_3Au
(d) CuAgAu

24. A solid PQ has rock salt type structure in which Q atoms are the corners of the unit cell. If the body-centred atoms in all the unit cells are missing, the resulting stoichiometry will be

(a) PQ (b) PQ_2
(c) P_3Q_4 (d) P_4Q_3

25. 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 resulting stoichiometry of the solid is

(a) AB_2
(b) A_2B
(c) A_4B_3
(d) A_3B_4

26. Xenon crystallizes in FCC lattice and the edge of the unit cell is 620 pm, then the radius of xenon atom is

(a) 219.20 pm (b) 438.5 pm
(c) 265.5 pm (d) 536.94 pm

27. Metallic gold crystallizes in FCC lattice with edge-length 4.07 Å. The closest distance between gold atoms is

(a) 3.525 Å (b) 5.714 Å
(c) 2.857 Å (d) 1.428 Å

28. The distance between two nearest neighbours in BCC lattice of axial length, *l*, is

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

29. Sodium metal crystallizes in BCC lattice with the cell edge, $a = 4.29$ Å. What is the radius of the sodium atom?

(a) 1.86 Å (b) 2.15 Å
(c) 4.29 Å (d) 2.94 Å

30. The unit cell of a metallic element of atomic mass 108 and density 10.5 g/cm^3 is a cube with edge length of 409 pm. The structure of the crystal lattice is

(a) FCC
(b) BCC
(c) edge-centred cubic
(d) simple cubic

31. An element (atomic mass = 100) having BCC structure has unit cell edge length 400 pm. The density of this element will be ($N_A = 6 \times 10^{23}$)

(a) 5.2 g/ml
(b) 10.4 g/ml
(c) 0.42 g/ml
(d) 2.6 g/ml

32. Potassium has BCC structure with nearest neighbour distance $(2.5 \times \sqrt{3})$ Å. Its density will be (K = 39, $N_A = 6 \times 10^{23}$)

(a) 1.040 kg/m^3 (b) 104 kg/m^3
(c) 520 kg/m^3 (d) 1040 kg/m^3

33. Lithium borohydride, $LiBH_4$, crystallizes in an orthorhombic system with four molecules per unit cell. The unit cell dimensions are: a = 6.0 Å, b = 4.4 Å and c = 7.5 Å. The density of crystals is (Li = 7, B = 11 $N_A = 6 \times 10^{23}$)

(a) 0.74 g/cm^3
(b) 1.48 g/cm^3
(c) 0.37 g/cm^3
(d) 0.90 g/cm^3

34. FeO crystallizes in the cubic system, in which there is four formula units in each unit cell. The density of the crystal is 4.0 g/cm^3. The side length of each unit cell is (Fe = 56, $N_A = 6 \times 10^{23}$)

(a) 4.227 Å (b) 2.424 Å
(c) 4.932 Å (d) 2.974 Å

35. α-form of iron exists in BCC form and γ-form of iron exists in FCC structure. Assuming that the distance between the nearest neighbours is the same in the two forms, the ratio of the density of γ-form to that of α-form is

(a) $4\sqrt{2}:3\sqrt{3}$ (b) $4\sqrt{3}:3\sqrt{2}$
(c) $\sqrt{3}:\sqrt{2}$ (d) 2:1

36. The number of atoms contained in a FCC unit cell of a diatomic molecular solid is

(a) 8 (b) 2
(c) 4 (d) 6

37. Packing fraction in simple cubic lattice is

(a) $\frac{1}{6}\pi$ (b) $\frac{\sqrt{2}}{6}\pi$
(c) $\frac{\sqrt{3}}{8}\pi$ (d) $\frac{1}{2}\pi$

38. Packing fraction in BCC lattice is

(a) $\frac{1}{6}\pi$ (b) $\frac{\sqrt{2}}{6}\pi$
(c) $\frac{\sqrt{3}}{8}\pi$ (d) $\frac{\sqrt{3}}{2}\pi$

39. Packing fraction in FCC lattice is

(a) $\frac{1}{6}\pi$ (b) $\frac{\sqrt{2}}{6}\pi$
(c) $\frac{\sqrt{3}}{8}\pi$ (d) $\frac{\sqrt{2}}{3}\pi$

40. In a BCC packing, the nearest neighbours lie along the

(a) edges of the cube
(b) face diagonal
(c) line joining the two opposite corners of the face
(d) cube diagonal

Types of Packing

41. The most malleable metals (Cu, Ag, Au) have close-packing of the type

(a) Hexagonal close packing (HCP)
(b) Simple cubic packing
(c) BCC packing
(d) Malleability is not related to type of packing

42. Number of carbon atoms per unit cell of diamond is

(a) 4 (b) 6
(c) 8 (d) 12

43. The number of closest neighbours of a carbon atom in diamond is

(a) 2 (b) 4
(c) 6 (d) 8

44. The number of closest neighbours of a carbon atom in graphite is

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

45. The low density of alkali metals is due to

(a) their BCC structure in which about 32% of the available space is unfilled.
(b) their HCP structure in which about 74% of the available space is unfilled.
(c) their cubic close packed (CCP) structure in which about 74% of the available space is unfilled.
(d) their BCC structure in which about 47% of the available space is unfilled.

46. The coordination number of a metal crystallizing in a HCP structure is

(a) 12 (b) 4
(c) 8 (d) 6

47. A metallic element crystallizes into a lattice containing a sequence of layers of ABABAB…. Any packing of spheres leaves out voids in the lattice. Approximately what percentage by volume of this lattice is empty space?

(a) 74% (b) 26%
(c) 48% (d) 32%

48. Which one of the following schemes of ordering close packed sheets of equal-sized spheres do not generate close packed lattice?

(a) ABACABAC….
(b) ABCBCABC….
(c) ABCABC….
(d) ABBAA….

49. Which of the following have the least void space fraction in their structure?

(a) BCC
(b) BCC and HCP
(c) HCP
(d) FCC and HCP

50. The number of tetrahedral and octahedral voids in hexagonal primitive unit cell is

(a) 8, 4 (b) 2, 1
(c) 12, 6 (d) 6, 12

51. Which void is smallest in close packing?

(a) tetrahedral
(b) octahedral
(c) cubic
(d) square

52. Which of the following interstitial site is formed when the three closed packed spheres of one layer is put over three closed packed spheres of the second layer, their positions being inverted with respect to each other?

(a) tetrahedral
(b) octahedral
(c) rhombohedral
(d) tetragonal

53. In an FCC arrangement of metallic atoms, what is the relative ratio of the sizes of tetrahedral and octahedral voids?

(a) 0.543 (b) 0.732
(c) 0.414 (d) 0.637

54. Atoms of the element ‘A’ form HCP and atoms of element ‘C’ occupy only two-third of octahedral voids in it, then the general formula of the compound is

(a) CA (b) CA_2
(c) C_2A_3 (d) C_3A_2

55. A solid has three types of atoms X, Y and Z. ‘X’ forms a FCC lattice with ‘Y’ atoms occupying all the tetrahedral voids and ‘Z’ atoms occupying half the octahedral voids. The simplest formula of solid is

(a) X_2Y_4Z
(b) XY_2Z_4
(c) X_4Y_2Z
(d) X_4YZ_2

Radius Ratio and Packing of Crystal

56. The ionic radii of Rb^+ and I^- are 1.46 and 2.16 Å, respectively. The most probable type of structure exhibited by it is

(a) CsCl type
(b) NaCl type
(c) ZnS type
(d) CaF_2 type

57. For an ideal ionic crystal, the simplest formula is AX and the coordination number of cation is 6. The value of radius ratio ($r_{A^+}:r_{X^-}$)

(a) must be greater than 0.732
(b) must lie in between 0.732 and 0.414
(c) must lie in between 0.414 and 0.225
(d) must be less than 0.414

58. In the zinc blende structure (ZnS), S^{2-} adopt CCP arrangement and Zn^{2+} occupy

(a) all octahedral voids
(b) only 50% of octahedral voids
(c) only 50% of tetrahedral voids
(d) all tetrahedral voids

59. The number of nest nearest neighbours of Cs^+ ion in CsCl crystal is

(a) 12 (b) 8
(c) 6 (d) 4

60. In calcium fluoride structure, the coordination numbers of calcium and fluoride ions are, respectively,

(a) 8 and 4 (b) 6 and 8
(c) 4 and 4 (d) 4 and 8

61. The radius of Ag^+ ion is 126 pm while of I^- ion is 216 pm. The co-ordination number of Ag in AgI is

(a) 2 (b) 4
(c) 6 (d) 8

62. A binary solid ($A^+ B^-$) has a rock salt structure. If the edge length is 400 pm and radius of cation is 75 pm, the radius of anion is

(a) 100 pm (b) 125 pm
(c) 250 pm (d) 325 pm

63. MgO exists in a rock salt type unit cell. Each Mg^{2+} ion will be in contact with

(a) 6 Mg^{2+} ions (b) 6 O^{2-} ions
(c) 8 O^{2-} ions (d) 4 O^{2-} ions

64. Sodium oxide has anti-fluorite structure. The percentage of the tetrahedral voids occupied by the sodium ions is

(a) 12% (b) 25%
(c) 50% (d) 100%

65. CsBr has been structure with edge length 4.3. The shortest inter ionic distance in between Cs^+ and Br^- is

(a) 3.72 (b) 1.86
(c) 7.44 (d) 4.3

66. In Na_2O structure

(a) O^{2-} ions constitute CCP and Na^+ ions occupy all the octahedral holes
(b) O^{2-} ions constitute CCP and Na^+ ions occupy all the tetrahedral holes
(c) O^{2-} ions constitute CCP and Na^+ ions occupy 50% of tetrahedral holes and 100% octahedral holes
(d) Na^+ ions constitute CCP and O^{2-} ions occupy half of octahedral holes

67. NaCl crystal is

(a) FCC (b) BCC
(c) HCP (d) simple Cubic

68. CsBr has CsCl type structure. Its density is 4.26 g/ml. The side of unit cell is (Cs = 133, Br = 80)

(a) 5.503 Å (b) 4.368 Å
(c) 3.225 Å (d) 2.856 Å

69. A solid contains A^{n+} and B^{m-} ions. The structure of solid is FCC for B^{m-} ions and A^{n+} ions are present in one-fourth of tetrahedral voids as well as in one fourth of octahedral voids. What is the simplest formula of solid?

(a) A_3B_4 (b) A_4B_3
(c) AB_2 (d) A_2B

70. An ionic solid is HCP of Q^{2-} ions and P^{x+} ions are in half of the tetrahedral voids. The value of x should be

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

71. In a compound, oxide ions are arranged in CCP arrangement. Cations A occupy one-sixth of the tetrahedral voids and cations B occupy one-third of the octahedral voids. The formula of the compound is

(a) AB_2O_4 (b) ABO_3
(c) ABO_2 (d) ABO_4

72. Sapphire is aluminium oxide. Aluminium oxide crystallizes with aluminium ions in two-third of the octahedral voids in the closest packed array of oxide ions. What is the formula of aluminium oxide?

(a) Al_2O_3
(b) AlO_2
(c) Al_3O_4
(d) Al_3O_2

73. What is the formula of the magnetic oxide of cobalt, used in recording tapes, that crystallizes with cobalt atoms occupying one-eighth of the tetrahedral holes and one half of the octahedral holes in a closest packed array of oxide ions?

(a) Co_2O_3 (b) Co_5O_8
(c) CoO (d) Co_3O_4

74. Caesium chloride, on heating, changes into

(a) CsCl (g)
(b) NaCl structure
(c) antifluorite structure
(d) ZnS structure

75. BaO has a rock salt type structure. When subjected to high pressure, the ratio of the coordination number of Ba^{2+} ion to O^{2-} ion changes to

(a) 4:8 (b) 8:4
(c) 8:8 (d) 4:4

Defects in Solids

76. Frenkel defect is noticed in

(a) AgBr
(b) Zns
(c) AgI
(d) All

77. Which of the following defect, if present, lowers the density of the crystal?

(a) Frenkel
(b) Schottky
(c) Metal excess defect due to excess cation
(d) interstitial defect

78. Schottky defect appears in

(a) NaCl (b) CsCl
(c) AgBr (d) All

79. The yellow colour of ZnO and conducting nature produced in heating is due to

(a) Metal excess of defects due to interstitial cation
(b) Extra positive ions present in an interstitial site
(c) Trapped electrons
(d) All

80. The presence of excess sodium in sodium chloride makes the crystal appearance yellow. This is due to the presence of

(a) Schottky defect
(b) Frenkel defect
(c) F-centres
(d) Interstitial defects

81. The composition of a sample of cuprous sulphide is found to be $Cu_{1.92}O_{1.00}$, due to metal deficient defect. The molar ratio of Cu^{2+} and Cu^{+} ions in the crystal is

(a) 4:5
(b) 1:12.5
(c) 1:23
(d) 1:24

82. NaCl is doped with 2×10^{-3} mole % $SrCl_2$, the concentration of cation vacancies is:

(a) 6.02×10^{18} mol^{-1}
(b) 1.204×10^{19} mol^{-1}
(c) 3.01×10^{18} mol^{-1}
(d) 1.204×10^{21} mol^{-1}

83. Each of the following statements is correct except

(a) the lattice positions left vacant by anion and occupied by electrons are called F-centres.
(b) the presence of F-centres makes the lattice electrically neutral and diamagnetic.
(c) the presence of F-centres gives colour to the crystals.
(d) F-centres contain unpaired electrons.

84. The intrinsic or thermodynamic defect is

(a) Schottky defect
(b) Metal excess defect due to excess cation
(c) Metal excess defect due to anion vacancy
(d) Metal-deficient defect

85. The only incorrect effect on density by the given defect in solids is

(a) Density must decrease by vacancy defect.
(b) Density must increase by interstitial defect.
(c) Density must increase by impurity defect.
(d) Density does not change by dislocation defect.

Properties of Solids

86. Which of the following is a ferromagnetic substance?

(a) Fe_2O_3
(b) Cr_2O_3
(c) Fe_3O_4
(d) CrO_2

87. Which of the following acts as a superconductor at 4 K?

(a) He
(b) Cu
(c) K
(d) Mg

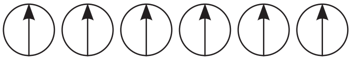
88. Superconductors are substances which

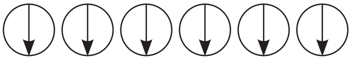
(a) conduct electricity at low temperatures.
(b) conduct electricity at high temperature.
(c) offer very high resistance to the flow of current.
(d) offer no resistance to the flow of current.

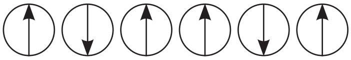
89. Addition of arsenic in small amount to pure germanium will result in the formation of

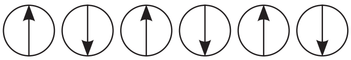
(a) n-type semiconductor
(b) germanium arsenide
(c) p-type semiconductor
(d) a superconducting alloy

90. Which of the following arrangement show schematic alignment of magnetic moments of anti-ferromagnetic substances?

(a) 

(b) 

(c) 

(d) 

Answer Keys – Exercise I

Basics

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

Analysis of Cubic Crystals

21. (a) 22. (b) 23. (c) 24. (c) 25. (d) 26. (a) 27. (c) 28. (b) 29. (a) 30. (a)
31. (a) 32. (d) 33. (a) 34. (c) 35. (a) 36. (a) 37. (a) 38. (c) 39. (b) 40. (d)

Types of Packing

41. (a) 42. (c) 43. (b) 44. (b) 45. (a) 46. (a) 47. (b) 48. (d) 49. (d) 50. (c)
51. (a) 52. (b) 53. (a) 54. (c) 55. (a)

Radius Ratio and Packing of Crystal

56. (b) 57. (b) 58. (c) 59. (c) 60. (a) 61. (c) 62. (b) 63. (b) 64. (d) 65. (a)
66. (b) 67. (a) 68. (b) 69. (a) 70. (b) 71. (b) 72. (a) 73. (d) 74. (b) 75. (c)

Defects in Solids

76. (d) 77. (b) 78. (d) 79. (c) 80. (c) 81. (c) 82. (b) 83. (b) 84. (a) 85. (c)

Properties of Solids

86. (d) 87. (a) 88. (d) 89. (a) 90. (d)

EXERCISE II (JEE ADVANCED)

Section A (Only one Correct)

1. For a certain crystal, the unit cell axial lengths are found to be $a = 5.62$ Å, $b = 7.41$ Å and $c = 10.13$ Å. The three coordinate axes are mutually perpendicular. The crystal system to which the crystal belongs is

   (a) tetragonal
   (b) orthorhombic
   (c) monoclinic
   (d) cubic

2. A metallic element exists as cubic lattice. Each edge of the unit cell is 4.0 Å. The density of the metal is 6.25 g/cm^3. How many unit cells will be present in 100 g of the metal?

   (a) 1.0×10^{22}
   (b) 2.5×10^{23}
   (c) 5.0×10^{23}
   (d) 2.0×10^{23}

3. Aluminium crystallizes in cubic system with unit cell edge length equal to 4.0 Å. If its density is $\frac{45}{16}$ g/cm^3, the atomic radius of Al-atom is

   (a) 1.414 Å
   (b) 1.732 Å
   (c) 4.0 Å
   (d) 2.0 Å

4. Is there an expansion or contraction as iron transform from HCP to BCC? The atomic radius of iron is 125 pm in HCP but $50\sqrt{2}$ pm in BCC.

   (a) Expansion
   (b) Contraction
   (c) Neither expansion nor contraction
   (d) Unpredictable

5. Silver (atomic mass = 108) has an atomic radius of 144 pm and density 10.6 g/cm^3. To which type of cubic crystal silver belongs?

   (a) simple
   (b) BCC
   (c) FCC
   (d) end-centred

6. Gold crystallizes with FCC lattice for which the side length of the unit cell is 5.0 Å. If the density of gold is 10.5 g/cm^3, the value of Avogadro number is (Au = 198)

   (a) 6.022×10^{23}
   (b) 6.034×10^{23}
   (c) 5.966×10^{23}
   (d) 6.022×10^{22}

7. What is the void space per unit cell for metallic silver crystallizing in the FCC system, the edge length of the unit cell being 4 Å?

   (a) 47.36 Å^3
   (b) 30.72 Å^3
   (c) 20.48 Å^3
   (d) 16.64 Å^3

8. A metal exists as FCC crystal. If the atomic radius is $100\sqrt{2}$ pm and the density of metal is 12,500 kg/m^3, the metal is (Atomic masses: Ca = 40, Co = 58.9, Sn = 119.8, Pb = 207.9; $N_A = 6 \times 10^{23}$)

   (a) Ca
   (b) Co
   (c) Sn
   (d) Pb

9. A solid element (monoatomic) exists in cubic crystal. If its atomic radius is 1.0 Å and the ratio of packing fraction and density is 0.1 cm^3/g, then the atomic mass of the element is ($N_A = 6 \times 10^{23}$)

   (a) 8π
   (b) 16π
   (c) 80π
   (d) 4π

10. In FCC unit cell, what fraction of edge is not covered by atoms?

    (a) 0.134
    (b) 0.293
    (c) 0.26
    (d) 0.32

11. The sublimation temperature of a substance is −83°C. It exist as cubic packed structure with unit cell edge length 5.0 Å and density $\frac{8}{3}$ g/cm^3, at −100°C. What should be density of substance at 0°C and 1 atm? ($N_A = 6 \times 10^{23}$)

(a) 50 g/cm^3
(b) 2.23 g/cm^3
(c) 2.23 g/l
(d) 1.86 g/l

12. An alkali metal has density 4.5 g/cm^3. It has cubic unit cell with edge length 400 pm. Reaction of 7.68 cm^3 chunk of the metal with an excess of HCl solution gives a colourless gas which occupies 4.54 L at 0°C and 1 bar. The unit cell of metal is

(a) Simple cubic
(b) BCC
(c) FCC
(d) End-centred

13. The densities of ice and water at 0°C and 1 bar are 0.96 and 0.99 g/cm^3, respectively. If the percentage of occupied space in ice is x, then the percentage of empty space in water is

(a) $\frac{32}{33}x$
(b) $\frac{33}{32}x$
(c) $100 - \frac{33}{32}x$
(d) $100 - \frac{32}{33}x$

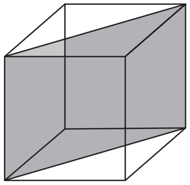
14. A metal crystallizes in such a lattice in which only 70% of the total space of the crystal is occupied by the atoms. If the atomic mass of the metal is 32π g/mol and the atomic radius is 0.2 nm, the density of the metal is

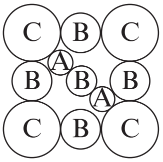
(a) 7.0 g/cm^3 (b) 3.5 g/cm^3
(c) 10.5 g/cm^3 (d) 14.0 g/cm^3

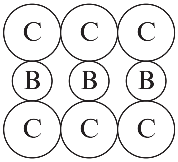
15. The number of octahedral voids per unit BCC cell is

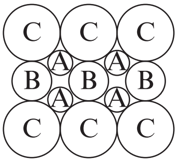
(a) 1.0 (b) 2.0
(c) 1.5 (d) 0

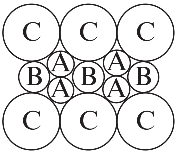
16. In a hypothetical solid, 'C' atoms form CCP lattice. 'A' atoms occupy all tetrahedral voids and 'B' atoms occupy all octahedral voids, without disturbing the crystal. If a unit cell of the crystal is cut by a plane shown in the figure, then the cross section of this plane looks like



(a)


(b)


(c)


(d)


17. A metal having atomic mass 60.22 g/mole crystallizes in ABCABC.... type packing. The density of each metal atom if the edge length of unit cell is 10 Å, is ($N_A = 6.022 \times 10^{23}$)

(a) 0.4 g/cm^3 (b) 40 g/cm^3
(c) 0.54 g/cm^3 (d) 54 g/cm^3

18. Packing fraction in 2D – hexagonal arrangement of identical spheres is

(a) $\frac{\pi}{3\sqrt{2}}$ (b) $\frac{\pi}{3\sqrt{3}}$
(c) $\frac{\pi}{2\sqrt{3}}$ (d) $\frac{\pi}{6}$

19. A close packing consists of a base of spheres, followed by a second layer where each sphere rests in the hollow at the junction of four spheres below it and the third layer then rests on these in an arrangement which corresponds exactly to that in the first layer. This packing is known as

(a) HCP
(b) CCP
(c) square close packing
(d) BCC packing

20. If the height of HCP unit cell of identical particles is h, then the height of octahedral voids from the base is

(a) $\frac{h}{2}$ (b) $\frac{h}{3}, \frac{2h}{3}$
(c) $\frac{h}{4}, \frac{3h}{4}$ (d) $\frac{h}{8}, \frac{7h}{8}$

21. If the volume occupied by a unit cell of NaCl is 4.7×10^{-23} ml, the volume of a crystal of NaCl weighing 1.0 g is

(a) 2.13×10^{22} ml
(b) 8.03×10^{-25} ml
(c) 0.48 ml
(d) 0.12 ml

22. If the unit cell length of sodium chloride crystal is 600 pm, then its density will be

(a) 2.165 g/cm^3
(b) 3.247 g/cm^3
(c) 1.79 g/cm^3
(d) 1.082 g/cm^3

23. The inter-metallic compound LiAg crystallizes in cubic lattice in which both Li and Ag have co-ordination number of 8. The class of crystal is

(a) Simple cubic
(b) BCC
(c) FCC
(d) End-centred cubic

24. A mineral having the formula AB_2 crystallizes in the CCP lattice, with the A atoms occupying the lattice points. What is the coordination number of the B atoms?

(a) 4 (b) 6
(c) 8 (d) 12

25. There are three cubic unit cells A, B and C. A is FCC and all of its tetrahedral voids are also occupied. B is also FCC and all of its octahedral voids are also occupied. C is simple cubic and all of its cubic voids are also occupied. If voids in all unit cells are occupied by the spheres exactly at their limiting radius, then the order of packing efficiency would be

(a) $A < B < C$ (b) $C < A < B$
(c) $C < B < A$ (d) $A < C < B$

26. In a cubic closest packed structure of mixed oxides, the lattice is made up of oxide ions. Tetrahedral voids are occupied by divalent X^{2+} ions and octahedral voids are occupied by trivalent Y^{3+} ions. If only 50% of the octahedral voids are occupied, then the percentage of tetrahedral voids occupied is

(a) 50% (b) 12.5%
(c) 25% (d) 40%

27. The distance between adjacent oppositely charged ions in rubidium chloride is 328.5 pm, in potassium chloride is 313.9 pm, in sodium bromide is 298.1 pm and in potassium bromide is 329.3 pm. The distance between adjacent oppositely charged ions in rubidium bromide is

(a) 314.7 pm (b) 338.5 pm
(c) 339.3 pm (d) 343.9 pm

28. Solid AB has a rock salt type structure. If the radius of the cation is 200 pm, what is the maximum possible radius of the anion?

(a) 483.1 pm (b) 273.6 pm
(c) 200 pm (d) 400 pm

29. The simplest formula of a solid having CCP arrangement for 'A' atoms in which alternate face-centres are occupied by 'B' atoms and alternate edge centres are occupied by 'C' atoms, is

(a) ABC
(b) A_4BC
(c) A_2BC
(d) A_4B_2C

30. Spinel is an important class of oxides consisting of two types of metal ions with the oxide ions arranged in CCP pattern. The normal spinel has one-eighth of the tetrahedral holes occupied by one type of metal ion and one-half of the octahedral hole occupied by another type of metal ion. Such a spinel is formed by Zn^{2+}, Al^{3+} and O^{2-}. The simplest formula of such spinel is

(a) $ZnAl_2O_4$
(b) Zn_2AlO_4
(c) $Zn_2Al_3O_4$
(d) $ZnAlO_2$

31. An ionic crystalline solid, MX_3, has a cubic unit cell. Which of the following arrangement of the ions is consistent with the stoichiometry of the compound?

(a) M^{3+} ions at the corners and X^- ions at the face centres
(b) M^{3+} ions at the corners and X^- ions at the body centres.
(c) X^- ions at the corners and M^{3+} ions at the face centres.
(d) X^- ions at the corners and M^{3+} ions at the body centres.

32. In a compound XY_2O_4, the oxide ions are arranged in CCP arrangement and cations X are present in octahedral voids. Cations Y are equally distributed between octahedral and tetrahedral voids. The fraction of the octahedral voids occupied is

(a) 1/2 (b) 1/4
(c) 1/6 (d) 1/8

33. Give the correct order of initials T (true) or F (false) for following statements:

I. In an anti-fluorite structure, anions form FCC and cations occupy all the tetrahedral voids.

II. If the radius of cation and anion is 20 and 95 pm, then the coordination number of cation in the crystal is 4.

III. An atom or ion is transferred from a lattice site to an interstitial position in Frenkel defect.

IV. Density of crystal always increases due to substitutional impurity defect.

(a) TTTT
(b) FFFF
(c) FFTT
(d) TFTF

34. The crystalline structure of a solid is CCP for 'X' atoms. If 'Y' atoms occupy all the octahedral voids and 'Z' atoms occupy all the tetrahedral voids, without any distortion in the CCP arrangement of 'X' atoms, then the fraction of body diagonal not covered by the atoms is

(a) 0.26
(b) 0.24
(c) 0.76
(d) 0.81

35. In an ionic solid AB_2O_4, the oxide ions form CCP. 'A' and 'B' are metal ions in which one is bivalent and another is trivalent (not necessarily in given order). If all the bivalent ions occupy octahedral holes and the trivalent ions occupy tetrahedral and octahedral voids in equal numbers, then the fraction of octahedral voids unoccupied is

(a) $\frac{1}{2}$ (b) $\frac{3}{4}$
(c) $\frac{1}{4}$ (d) $\frac{7}{8}$

36. The theoretical density of ZnS is d g/cm^3. If the crystal has 4% Frenkel defect, then the actual density of ZnS should be

(a) d g/cm^3
(b) $0.04d$ g/cm^3
(c) $0.96d$ g/cm^3
(d) $1.04d$ g/cm^3

37. In a crystal, at 827°C, one out of 10^{10} lattice site is found to be vacant but at 927°C, one out of 2×10^9 lattice sites is found to be vacant. The enthalpy of vacancy formation, in kJ/mol, is

(a) 76.8 (b) 176.8
(c) 33.8 (d) 23.8

38. Which of the following oxide shows electrical properties like metals?

(a) SiO_2 (b) MgO
(c) $SO_2(s)$ (d) CrO_2

39. Which kind of defects is introduced by doping in silicon crystal?

(a) Dislocation defect
(b) Schottky defect
(c) Frenkel defect
(d) Electronic defect

40. A ferromagnetic substance becomes a permanent magnet when it is placed in a magnetic field because

(a) all the domains get oriented in the direction of magnetic field.
(b) all the domains get oriented in the direction opposite to the direction of magnetic field.
(c) domains get oriented randomly.
(d) domains are not affected by magnetic field.

Section B (One or More than one Correct)

1. Which of the following solid substance(s) will have the same refractive index when measured in different directions?

(a) Rubber (b) NaCl
(c) Plastic (d) Graphite

2. Which is/are amorphous solid(s)?

(a) NaCl (b) CaF_2
(c) Glass (d) Plastic

3. Which of the following has face-centred Bravais lattice?

(a) Hexagonal (b) Monoclinic
(c) Cubic (d) Orthorhombic

4. If the height of HCP unit cell of identical particles is h, then the height of tetrahedral voids from the base is

(a) $\frac{3h}{8}, \frac{5h}{8}$ (b) $\frac{h}{3}, \frac{2h}{3}$
(c) $\frac{h}{4}, \frac{3h}{4}$ (d) $\frac{h}{8}, \frac{7h}{8}$

5. The correct information regarding a solid element (atomic radius = r) having ABCABC…. type packing (FCC unit cell edge length = a) is

(a) the distance between nearest octahedral and tetrahedral void is $\frac{\sqrt{3}\,a}{4}$.
(b) the distance between two nearest octahedral void is $\frac{a}{\sqrt{2}}$.
(c) the distance between two nearest tetrahedral void is $\frac{\sqrt{3}\,a}{2}$.
(d) the distance between successive A and B layers is $2r.\sqrt{\frac{2}{3}}$.

6. An element exists in two allotropic forms. One form is CCP and the other form is HCP arrangement of atoms of the element. If the atomic radius of element is same in both the forms, then both allotropic forms have the same

(a) density
(b) coordination number
(c) fraction of unoccupied space
(d) distance between two consecutive layers

7. The correct statement(s) for the packing of identical spheres in two dimensions is/are

(a) For square close packing, the coordination number is 4.
(b) For HCP, the coordination number is 6.
(c) There is only one void per sphere in both, square and HCP.
(d) HCP is more efficiently packed than square close packing.

8. Which of the following information(s) is/are incorrect regarding the voids formed in three dimensional HCP of identical spheres?

(a) A tetrahedral void is formed when a sphere of the second layer is present above the triangular void of the first layer.
(b) All the triangular voids are not covered by the spheres of the second layer.
(c) Tetrahedral voids are formed when the triangular voids in the second layer lie above the triangular voids in the first layer and the triangular shapes of these voids do not overlap.
(d) Octahedral voids are formed when the triangular voids in the second layer exactly overlap with similar voids in the first layer.

9. Which of the following statement(s) is (are) correct?

(a) The coordination number of each type of ions in CsCl crystal is 8.
(b) A metal that crystallizes in BCC structure has a coordination number of 12.
(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.($r_{Na^+} = 95$ pm, $r_{Cl^-} = 181$ pm)

10. In which of the following crystals, alternate tetrahedral voids are occupied?

(a) NaCl (b) ZnS
(c) CaF_2 (d) Na_2O

11. Which of the following statement(s) is/are correct with respect to zinc blende structure?

(a) Zn^{2+} ions are present at the corners and at the centres of each face.
(b) Only alternate tetrahedral holes are occupied by Zn^{2+} ions.
(c) The coordination number of Zn^{2+} and S^{2-} is 4 each.
(d) The number of ZnS units in a unit cell is 4.

12. In sodium chloride crystal, the unit cell edge length is *a*. The option(s) representing correct combination is/are

Options	Nearest neighbour of Na^+ ion	Ion	Distance from Na^+ ion	Number of ions
(a)	2nd	Na^+	0.707*a*	12
(b)	3rd	Cl^-	0.866*a*	8
(c)	4th	Na^+	*a*	6
(d)	5th	Cl^-	1.12*a*	24

13. A quantity of 80.0 g of a salt (XY) of strong acid and weak base is dissolved in water to form 2.0 L aqueous solution. At 298 K, pH of the solution is found to be 5.0. If XY forms CsCl type crystal and the radius of X^+ and Y^- ions are 160 pm and 186.4 pm, respectively, then the correct information is (Given: K_b of XOH $= 4 \times 10^{-5}$, $N_A = 6 \times 10^{23}$)

(a) molar mass of the salt is 100 g/mol
(b) the degree of hydrolysis of salt is 2.5×10^{-5}
(c) unit cell edge length of XY crystal is 400 pm
(d) density of solid XY is 2.6 g/cm^3

14. An ionic compound consists of only A^+, B^{2+} and C^{3-} ions. Which of the following option(s) is/are correct with respect to their possible structure?

(a) C^{3-} ions form CCP, A^+ ions occupy all octahedral voids and B^{2+} ions occupy half of the tetrahedral voids.
(b) B^{2+} ions form HCP, A^+ ions occupy all octahedral voids and C^{3-} ions occupy half of the tetrahedral voids.
(c) A^+ ions occupy alternate corners of a simple cube, B^{2+} ions occupy the other corners of the cube and C^{3-} ions occupy body centre of the cube.
(d) A^{2+} ions form CCP, C^{3-} ions occupy all the tetrahedral voids and A^+ ions occupy all the octahedral voids.

15. Potassium hexachloroplatinate (IV), $K_2[PtCl_6]$ adopts anti-fluorite crystal structure. The correct information(s) about ideal $K_2[PtCl_6]$ crystal is/are

(a) K^+ ions occupy all the tetrahedral voids.
(b) The unit cell is FCC with respect to $PtCl_6^{2-}$ ions.
(c) The coordination number of $PtCl_6^{2-}$ ions is 4.
(d) The coordination number of $PtCl_6^{2-}$ ions is 8.

16. In each of the following ionic solids, the coordination number of the cation and anion is same, except

(a) MgO
(b) CaF_2
(c) Al_2O_3
(d) CsCl

17. Which of the following defects in the crystals may lower the density?

(a) Interstitial defect
(b) Vacancy defect
(c) Schottky defect
(d) Impurity defect

18. Which of the following may have Frenkel defect?

(a) Sodium chloride
(b) Zinc sulphide
(c) Silver bromide
(d) Diamond

19. Which of the following statement(s) is/are incorrect regarding the defects in solids?

(a) AgBr crystal show both Schottky and Frenkel defect.
(b) Impurity defect by doping of Arsenic in Silicon results 'n'-type semiconductor.
(c) Doping in crystal introduces dislocation defect.
(d) Metal deficient defect can occur with extra anion present in the interstitial voids.

20. The correct statement(s) regarding defects in solid is (are)

(a) Frenkel defect is usually favoured by a very small difference in the sizes of cation and anion.
(b) Frenkel defect is a dislocation defect.
(c) Trapping of an electron in the lattice leads to the formation of F-centre.
(d) Schottky defect have no effect on the physical properties of solids.

21. Which of the following is/are correct regarding point defects in solids?

(a) The density of point defect increases with the increase in rate of crystallization.
(b) In the formation of point defects, the entropy of system increases but the entropy of surrounding decreases.
(c) The density of point defect increases with the increase in temperature.
(d) All point defects results decrease in the density of the solid.

22. Which of the following is/are correct statement(s) about Fe_3O_4 crystal?

(a) Fe^{2+} ions occupy octahedral voids
(b) Fe^{3+} ions occupy tetrahedral voids
(c) Fe^{3+} ions occupy octahedral as well as tetrahedral voids
(d) O^{2-} ions are present at the corner as well as the centre of alternate faces.

23. Which of the following statement(s) is/are true regarding the electrical properties of solids?

(a) (Conductivity) metals << (Conductivity) insulators < (Conductivity) semiconductors.
(b) Depending upon temperature, TiO_3 can behave as insulator or conductor.
(c) $I_2(s)$ is non-conducting.
(d) n-type semiconductor will have conductivity less than pure semiconductor.

24. Which of the following solids is not an electrical conductor?

(a) Mg(s) (b) TiO(s)
(c) $I_2(s)$ (d) $H_2O(s)$

25. Which of the following oxides behaves as a conductor or an insulator depending on temperature?

(a) TiO (b) SiO_2
(c) TiO_3 (d) VO

Section C (Comprehensions)

Comprehension I

Potassium crystallizes in BCC lattice, with a unit cell length, $a = 5.0$ Å. (K = 39)

1. What is the distance between nearest neighbours?

(a) 5.0 Å (b) 4.33 Å
(c) 3.54 Å (d) 2.5 Å

2. What is the distance between next nearest neighbours?

(a) 5.0 Å
(b) 4.33 Å
(c) 3.54 Å
(d) 7.07 Å

3. How many nearest neighbours does each K atom have?

(a) 8 (b) 6
(c) 4 (d) 12

4. How many next nearest neighbours does each K atom have?

(a) 8 (b) 6
(c) 4 (d) 12

5. What is the theoretical density of crystalline K?

(a) 10.4 g/cm^3 (b) 20.8 g/cm^3
(c) 1.04 g/cm^3 (d) 2.08 g/cm^3

6. If the metal is melted, the density of molten metal is found to be 0.9 g/cm^3. What is the percentage of empty space in the molten metal?

(a) 82.06% (b) 62.06%
(c) 17.94% (d) 37.94%

Comprehension II

Copper has a FCC lattice with a unit cell edge length of $\frac{0.5}{\sqrt{2}}$ nm.

7. What is the size of the largest atom that could be fit into octahedral holes of the lattice without disturbing the lattice?

(a) $\frac{0.207}{\sqrt{2}}$ nm (b) $\frac{0.366}{\sqrt{2}}$ nm
(c) 0. 092 nm (d) 0.052 nm

8. What is the size of the largest atom that could be fit into tetrahedral holes of the lattice without disturbing the lattice?

(a) 0.028 nm (b) 0.052 nm
(c) $\frac{0.1125}{\sqrt{2}}$ nm (d) $\frac{0.207}{\sqrt{2}}$ nm

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Comprehension III

The crystalline structure of magnesium is HCP. The density of magnesium is 1.92 g/cm^3. [Mg = 24, $N_A = 6 \times 10^{23}$, $3\sqrt{2} = \frac{4\pi}{3} = (1.6)^3$, $\sqrt{\frac{2}{3}} = 0.8$]

9. What is the volume of the unit cell?

(a) 1.25×10^{-22} cm^3
(b) 2.50×10^{-22} cm^3
(c) 6.25×10^{-21} cm^3
(d) 1.25×10^{-23} cm^3

10. What is the atomic radius of magnesium?

(a) 5.0 Å (b) 1.56 Å
(c) 3.125 Å (d) 2.13 Å

11. What is the height of the unit cell?

(a) 6.24 Å (b) 2.496 Å
(c) 4.992 Å (d) 3.12 Å

12. How many nearest neighbours does each atom have?

(a) 6 (b) 9
(c) 12 (d) 3

Comprehension IV

Titanium crystallizes in a FCC lattice. It reacts with carbon or hydrogen interstitially, by allowing atoms of these elements to occupy holes in the host lattice. Hydrogen occupies tetrahedral holes, but carbon occupies octahedral holes.

13. Predict the formulas of titanium hydride and titanium carbide formed by saturating the titanium lattice with either 'foreign' element.

(a) TiH, TiC
(b) TiH_2, TiC
(c) TiH_4, TiC
(d) TiH_2, TiC_2

14. Account for the fact that hydrogen occupies tetrahedral holes while carbon occupies octahedral holes.

(a) $r_H = r_C$
(b) $r_H < r_C$
(c) $r_H > r_C$
(d) Hydrogen is more reactive than carbon

Comprehension V

KCl crystallizes in the same type of lattice as does NaCl (rock salt structure). Given that $r_{Na^+}/r_{Cl^-} = 0.5$ and $r_{Na^+}/r_{Cl^-} = 0.7$.

15. The ratio of the side of the unit cell for KCl to that for NaCl is

(a) 1.143
(b) 2.57
(c) 2.4
(d) 1.2

16. The ratio of density of NaCl to that of KCl is

(a) 1.49
(b) 1.17
(c) 0.853
(d) 1.143

Comprehension VI

$BaTiO_3$ crystallizes in the perovskite structure. This structure may be described as a cubic lattice, with barium ions occupying the corners of the unit cell, oxide ions occupying the face centres and titanium ions occupying the centres of the unit cells.

17. If titanium is described as occupying holes in Ba-O lattice, what type of holes does it occupy?

(a) tetrahedral
(b) octahedral
(c) cubic
(d) triangular

18. What fraction of the holes of this type does it occupy?

(a) 0.25
(b) 0.50
(c) 1.00
(d) 0.75

Comprehension VII

The zinc blend structure is cubic. The unit cell may be described as a face-centred sulphide ion sub-lattice with zinc ions in the centres of alternating mini cubes made by partitioning the main cube into 8 equal parts.

19. How many nearest neighbours does each Zn^{2+} have?

(a) 4 (b) 6
(c) 8 (d) 2

20. How many nearest neighbours does each S^{2-} have?

(a) 4
(b) 6
(c) 8
(d) 2

21. What angle is made by the lines connecting any Zn^{2+} to any two of its nearest neighbours?

(a) 120° (b) 90°
(c) 109°28′ (d) 60°

22. What minimum r^+/r^- ratio is needed to avoid anion-anion contact, if closest cation–anion pairs are assumed to touch?

(a) 2.25 (b) 0.225
(c) 0.525 (d) 5.25

Comprehension VIII

A cubic unit cell contains manganese ions at the corners and fluoride ions at the centre of each edge. (Mn = 55, F = 19, $N_A = 6 \times 10^{23}$)

23. What is the empirical formula?

(a) MnF (b) MnF_2
(c) MnF_3 (d) MnF_4

24. What is the co-ordination number of the Mn ion?

(a) 4 (b) 6
(c) 8 (d) 12

25. The edge length of the unit cell, if the radius of Mn ion is 0.65 Å and that of F^- ion is 1.35 Å, is

(a) 2.00 Å (b) 4.00 Å
(c) 3.82 Å (d) 1.30 Å

26. The density of solid is

(a) 2.92 g/cm^3 (b) 5.84 g/cm^3
(c) 8.75 g/cm^3 (d) 23.33 g/cm^3

Comprehension IX

The density of crystalline CsCl is 3.5 g/cm^3. [Cs = 132.5, Cl = 35.5, $N_A = 6 \times 10^{23}$, $(4.3)^3 = 80$].

27. The volume effectively occupied by a single CsCl ion pair in the crystal is

(a) 48 ml
(b) 8×10^{-23} ml
(c) 3.2×10^{-22} ml
(d) 2×10^{-23} ml

28. The smallest Cs-to-Cs inter-nuclear distance in the crystal is

(a) 2.0 Å (b) 4.3 Å
(c) 3.72 Å (d) 6.08 Å

29. The smallest Cs-to-Cl inter-nuclear distance in the crystal is

(a) 2.0 Å
(b) 4.3 Å
(c) 3.72 Å
(d) 6.08 Å

Comprehension X

The moles of Schottky and Frenkel defects in an ionic crystal is given as: $N = N_o \cdot e^{-E/2RT}$ and $\sqrt{N_o \cdot N_i} \cdot e^{-E/2RT}$, where N_o is the number of ideal lattice points, N_i is the number of available interstitial sites and E is the activation energy of the formation of respective defect. For NaCl crystal, the activation energies of formation of these defects are 46 and 73.6 kcal/mol, respectively. (ln 10 = 2.3)

30. The mole fraction of Schottky defects in a NaCl crystal at 1000 K is

(a) 1.0×10^{-5}
(b) 1.41×10^{-8}
(c) 2.0×10^{-5}
(d) 5.0×10^{-6}

31. The mole fraction of Frenkel defects in a NaCl crystal at 1000 K is

(a) 1.0×10^{-5}
(b) 1.41×10^{-8}
(c) 1.0×10^{-8}
(d) 2.0×10^{-8}

Comprehension XI

The crystal AB (rock salt structure) has molecular mass 6.023 y amu, where y is an arbitrary number in amu. If the minimum distance between cation and anion is $y^{1/3}$ nm and the observed density is 20 kg/m^3.

32. The theoretical density of AB(s) in kg/m^3 is

(a) 20.0 kg/m^3 (b) 5.0 kg/m^3
(c) 10.0 kg/m^3 (d) 2.5 kg/m^3

33. The type of defect in solid is

(a) Frenkel defect
(b) Schottky defect
(c) Metal excess defect
(d) Impurity defect

Comprehension XII

Silicon carbide (carborundum) (SiC) and diamond are covalent solids which crystallize in cubic structures. In SiC, carbon atoms occupy lattice points of the FCC lattice and silicon atoms occupy half of the tetrahedral voids available. In diamond, the same tetrahedral voids are occupied by carbon atoms. The densities of SiC and diamond are 3.2 and 3.6 g/cm^3, respectively. (Si = 28)

34. The radius of carbon atom is

(a) 0.76 Å (b) 1.12 Å
(c) 3.2 Å (d) 3.6 Å

35. The radius of silicon atom is

(a) 0.76 Å (b) 1.12 Å
(c) 3.2 Å (d) 3.6 Å

36. Which of the following will not change the density of solid SiC?

(a) Substitution of some Si-atoms by some C-atoms.
(b) Schottky defect
(c) Interchange of position of Si and C-atoms.
(d) Decrease in temperature of solid.

37. If the similar volume of SiC and diamond are considered, which of the following is the true statement?

(a) The number of Si-atoms in SiC is 3.75 times the number of C-atoms in diamond.
(b) The number of C-atoms in diamond is 3.75 times the number of Si-atoms in SiC.
(c) The number of SiC formula units is 3.75 times the number of C-atoms in diamond.
(d) The number of C-atoms in diamond is 3.75 times the number of SiC formula units.

38. Which of the following is incorrect statement?

(a) The packing efficiency of SiC is greater than that of diamond.
(b) The coordination number of Si and C-atoms in SiC is same.
(c) The number of C–C bonds per unit cell in diamond is 16.
(d) The coordination number of C-atoms in SiC is half of that of C-atoms in diamond.

Section D (Assertion – Reason)

The following questions consist of two statements. Mark

(a) If both statements are CORRECT, and **Statement II** is the CORRECT explanation of **Statement I**.

(b) If both statements are CORRECT, and **Statement II** is NOT the CORRECT explanation of **Statement I**.

(c) If **Statement I** is CORRECT, but **Statement II** is INCORRECT.

(d) If **Statement I** is INCORRECT, but **Statement II** is CORRECT.

1. **Statement I:** In close packing of spheres, a tetrahedral void is surrounded by four spheres whereas as octahedral void is surrounded by six spheres.

   Statement II: A tetrahedral void has a tetrahedral shape whereas as octahedral void has an octahedral shape.

2. **Statement I:** In an FCC unit cell, packing efficiency is more when all tetrahedral voids are occupied by the spheres of maximum possible size as compared with the packing efficiency when all octahedral voids are occupied in similar way.

   Statement II: Tetrahedral voids are more in number than octahedral voids in FCC

3. **Statement I:** Distance between nearest lattice points in BCC is greater than the same in FCC having the same edge length.

   Statement II: FCC has greater packing efficiency than BCC.

4. **Statement I:** Only metallic, never ionic or covalent substances, form crystals exhibiting the maximum coordination number of twelve among like-sized atoms.

   Statement II: In metallic crystals, the forces are non-directional and hence arrangement of atoms frequently corresponds to the closest packing of spheres.

5. **Statement I:** In a closest packed structure, the number of octahedral voids is equal to the number of atoms present.

   Statement II: Octahedral voids are located midway between the two closest packed layers.

6. **Statement I:** In a closest packed structure, the number of tetrahedral voids is twice the number of atoms present.

   Statement II: Tetrahedral voids are located above each atom in the first layer and below each atom in the second layer.

7. **Statement I:** Atomic solids having a particular type of unit cells have fixed density irrespective of the identity of atoms.

   Statement II: Atomic solids crystallizing in a particular type of unit cell have a fixed value of packing fraction irrespective of the identity of atoms.

8. **Statement I:** When an element crystallizes in either CCP or HCP arrangement, the density of solid remains the same in both the arrangements.

   Statement II: Both CCP and HCP arrangements have the same packing fractions.

9. **Statement I:** The melting point of diamond is very high.

   Statement II: Diamond has very high packing efficiency.

10. **Statement I:** In sodium chloride crystal, the Na^+ ion occupies the octahedral void while Cl^- ions occupy the vertices of octahedron.

    Statement II: The radius ratio (r_{Na^+}/r_{Cl^-}) lies between 0.414 and 0.732.

11. **Statement I:** In any ionic solid (MX) with Schottky defects, the number of positive and negative ions are same.

Statement II: Equal numbers of cation and anion vacancies are present.

12. **Statement I:** Anion vacancies in alkali metal halides are produced by heating the alkali halide crystals with alkali metal vapour.

Statement II: Electrons trapped in anion vacancies are referred to as F-centres.

13. **Statement I:** Due to Frenkel defect, there is no effect on the density of the crystalline solid.

Statement II: In Frenkel defect, no cation or anion leaves the crystal.

14. **Statement I:** Frenkel defects are found in silver halides.

Statement II: Frenkel defects are commonly found in ionic solids having cations sufficiently smaller than anions.

15. **Statement I:** Increasing temperature increases the density of point defects.

Statement II: The process of formation of point defects in solids is endothermic and has $\Delta S > 0$.

16. **Statement I:** KCl is more likely to show Schottky defect while LiI is more likely to show Frenkel defect.

Statement II: Schottky defect is more likely in ionic solids in which cations and anions are of comparable size while Frenkel defect is more likely in ionic solids in which cations and anions have large differences in their ionic sizes.

17. **Statement I:** Conductivity of silicon increases by doping it with group 15 elements.

Statement II: Doping means introduction of small amount of impurities like P, As or Bi into the pure silicon crystal.

18. **Statement I:** On heating ferromagnetic or ferrimagnetic substances, they become paramagnetic.

Statement II: The electrons change their spin on heating.

19. **Statement I:** Anti-ferromagnetic substances possess zero magnetic moment.

Statement II: MnO is an anti-ferromagnetic substance.

20. **Statement I:** The substances whose resistance reduces nearly to zero are called superconductors.

Statement II: Superconductors are diamagnetic substances.

Section E (Column Match)

1. Match column I with column II and column III (l = Edge length of unit cell, r = radius of spherical constituent unit)

Column I	Column II	Column III
(A) Simple cubic unit cell	(P) $l\sqrt{2} = 4r$	(U) 74% occupied space
(B) FCC unit cell	(Q) $l = 2r$	(V) 67.98 occupied space
(C) BCC unit cell	(R) $l\sqrt{3} = 4r$	(W) 52.33% occupied space

2. Match Column I with Column II and Column III

Column I	Column II	Column II
(A) NaCl	(P) FCC, anion in all tetrahedral voids	(W) Cation (6), anion (6)
(B) CaF_2	(Q) FCC, cation in all octahedral voids	(X) Cation (8), anion (4)
(C) ZnS (zinc blende)	(R) FCC, cation in alternate tetrahedral voids	(Y) Cation (4), anion (8)
(D) Na_2O	(S) FCC, cation in all tetrahedral voids	(Z) Cation (4), anion (4)

3. Associate each type of solid in the left-hand column with two of the properties in the right-hand column. Each property may be used more than once.

Column I	Column II
(A) molecular solid	(P) low-melting
(B) ionic solid	(Q) high-melting
(C) metallic acid	(R) brittle
(D) covalent network solid	(S) malleable hard
	(T) electrically conducting

4. Match the solids in column I with the properties in column II

Column I	Column II
(A) Germanium	(P) a non-conducting solid becoming good conductor on melting
(B) Potassium chloride	(Q) a high melting solid involving covalent bonded atoms
(C) Sodium	(R) a solid melting far below room temperature and held together by Van der Waal's forces
(D) Solid methane	(S) a solid having melting point about 373 K and very good conductor of electricity.

5. Match the solids in column I with the properties in column II

Column I	Column II
(A) Cobalt	(P) A white solid melting at 613°C; the liquid is electrically conducting, although the solid is not.
(B) Iodoform	(Q) A very hard, blackish solid subliming at 2700°C
(C) Lithium chloride	(R) A yellow solid with a characteristic odour having a melting point of 120°C
(D) Silicon carbide	(S) A grey, lustrous solid melting at 1495°C; both the solid and liquid are electrical conductors.

6. Match the column ('l' is the unit cell edge length)

Column I	Column II
(A) 0.866 l	(P) Shortest distance between cation and anion in CsCl crystal
(B) 0.707 l	(Q) Shortest distance between two cations in CaF_2 crystal
(C) 0.433 l	(R) Shortest distance between carbon atoms in diamond
	(S) Shortest distance between two cations in rock salt crystal

7. Match the column

Column I	Column II
(A) Rock salt structure	(P) Coordination number of cation is 4
(B) Zinc blend structure	(Q) $\frac{\sqrt{3}\,a}{4} = r^+ + r^-$
(C) Fluorite structure	(R) Coordination number of cation and anion is same
	(S) Distance between two nearest anion is $\frac{a}{\sqrt{2}}$

8. Match the crystal system/unit cells mentioned in Column I with their characteristic features mentioned in Column II

Column I	Column II
(A) Simple cubic and FCC	(P) have these cell parameters $a = b = c$ and $\alpha = \beta = \gamma$
(B) Cubic and rhombohedral	(Q) are two crystal systems
(C) Cubic and tetragonal	(R) have only two crystallographic angles of 90°
(D) Hexagonal and monoclinic	(S) belongs to same crystal system

9. Match the Column I having different characteristics with Column II having different type of unit cell

Column I	Column II
(A) At least two interfacial angles be 90°	(P) Unit cell of monoclinic sulphur
(B) At least two crystallographic axis length	(Q) Unit cell of diamond be same
(C) None of the axial lengths to be same	(R) Orthorhombic crystal
(D) None of the interfacial angles to be same	(S) Tetragonal crystal
	(T) Triclinic crystal

10. Match the columns (assume the unit cell edge length equal to a)

Column I	Column II
(A) a	(P) two times the smallest distance between two similarly charged ions in fluorite structure
(B) $\frac{a}{\sqrt{2}}$	(Q) distance between next nearest cations in NaCl structure
(C) $\sqrt{3}\,a$	(R) distance between next nearest anion in CsCl structure
(D) $\sqrt{2}\,a$	(S) four times the smallest distance of tetrahedral voids from the corner of FCC unit cell.
	(T) smallest distance between next nearest similarly charged ions in anti-fluorite structure.

11. Match the columns (assume the unit cell edge length equal to a)

Column I	Column II
(A) a	(P) distance between nearest particle in simple cubic crystal
(B) $\dfrac{a}{\sqrt{2}}$	(Q) distance between nearest particle in BCC crystal
(C) $\dfrac{\sqrt{3}}{2}a$	(R) distance between nearest particle in FCC crystal
(D) $\sqrt{2}\,a$	(S) distance between next nearest particle in simple cubic crystal
	(T) distance between next nearest particle in BCC crystal

Section F (Subjective)

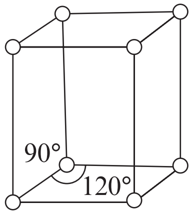
Single-digit Integer Type

1. The density of crystalline sodium is 2.167 g/cm^3. What would be the side length (in cm) of cube containing one mole of NaCl?

2. Iron(II) oxide crystal has a cubic structure and each edge of the unit cell is 0.493 nm. If the density of the oxide as 4.0 g/cm^3, the number of iron (II) oxide formula units in each unit cell is (Fe = 56)

3. Methane crystallizes in a cubic unit cell with edge length 0.6 nm. The density of solid CH_4 is only slightly greater than the density of liquid CH_4. If the density of liquid CH_4 is 0.5 g/cm^3, the number of CH_4 molecules per unit cell is

4. Ice crystallizes in a hexagonal lattice. At the low temperatures at which the structure was determined, the lattice constants were a = 4.53 Å and b = 7.41 Å as shown in the figure. How many H molecules are contained in a unit cell? (Given that density of ice = 0.92 g/cm^3)



5. The density of graphite is 2.4 g/ml and the spacing between the layers is found by X-ray diffraction to be $2\sqrt{3}$ Å. If the carbon–carbon distance in the molecular layers is x Å, then the value of $1.08 \times x^2$ is

6. X-ray diffraction analysis of crystalline C_{60} (buckminsterfullerene) shows that the crystal structure at 300 K can be regarded as FCC with a one-molecule basis and unit cell edge length of $\sqrt{2}$ nm; the molecules are orientationally disordered due to rotation. The centre-to-centre distance (in nm) between nearest neighbour C_{60} molecules in the solid at 300 K is

7. KF crystallizes in the NaCl type structure. If the radius of K^+ ion is $\dfrac{186}{\sqrt{2}}$ pm and F^- ion is $\dfrac{214}{\sqrt{2}}$ pm, what is the shortest distance between $K^+ - K^+$ ions (in Å)?

8. X-ray diffraction shows that the unit cell edge length of NaCl is 500 pm. If the measured density of NaCl is 2.964 g/ml, what per cent of Na^+ and Cl^- ions must be missing?

9. The following are some statements related with solid state of matter:

(i) All crystalline solids are isotropic.

(ii) Amorphous solids are super cooled liquids with high viscosity.

(iii) In crystals, short range order exists.

(iv) Unit cell is the smallest building unit in the crystals.

(v) Every object possesses an identity element.

(vi) Each lattice point in a crystal has the same environment.

(vii) The basic unit must have the same stoichiometric composition as the entire crystal.

(viii) A crystal space lattice cannot have a positive ion at one lattice point and a negative ion at another lattice point.

The number of true statements is

10. A metal 'M' (atomic mass = 31.25) crystallizes in CCP but it has some vacancy defect. If the edge length of the unit cell is 500 pm and the density of the metal is 1.6075 g/cm^3, then the number of moles of metal atoms missing per litre of the crystal is (1 amu = 1.67×10^{-24} g)

11. The total number of ions per unit cell in sphalerite (zinc blend) structure if there is a Schottky defect of one anion per unit cell, is

12. The number of hexagonal faces that are present in a truncated octahedron is

13. A metal (atomic mass = 307.2) exist in BCC structure. If the uncovered distance between the atoms along the edge is equal to 120 pm, the density of crystal (in g/cm^3) is ($N_A = 6 \times 10^{23}$, $\sqrt{3} = 1.732$)

14. A strong current of trivalent gaseous boron passed through a silicon crystal decreases the density of the crystal due to part replacement of silicon by boron and due to interstitial vacancies created by missing Si atoms. In one such experiment, one gram of silicon is taken and the boron atoms are found to be 1000 ppm, by mass, when the density of the Si crystal decreases by 12%. The percentage of missing vacancies due to silicon, which are filled up by boron atoms is (Atomic masses: Si = 30, B = 11)

15. The number of square faces in a truncated octahedron is 'x' and the number of carbon atoms per unit cell in diamond is 'y', then the value of $(x - y)$ is

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Four-digit Integer Type

1. Gold has a close packed structure which can be viewed as spheres occupying 0.74 of the total volume. If the density of gold is 19.7 g/ml, the atomic radius of gold (in pm) is [Au = 197, $(1.43)^3 \times 4\pi = 37$]

2. The approximate percentage of vacant space in a Silicon cubic cell having crystal structure similar to diamond

3. Insulin forms crystals of orthorhombic type with unit cell dimensions of $12.5 \times 8.0 \times 3.0$ nm^3. If the density of the crystal is 1.5×10^3 kg/m^3 and there are six insulin molecules per unit cell, the molar mass of insulin (in kg/mol) is

4. The olivine series of minerals consists of crystals in which Fe and Mg ions may substitute for each other. The density of forsterite (Mg_2SiO_4) is 3.3 g/ml and that of fayalite (Fe_2SiO_4) is 4.2 g/ml. What is the percentage of fayalite in an olivine with a density of 3.9 g/ml?

5. The unit cell of $TlAl(SO_4)_2 \cdot xH_2O$ is FCC with $a = 1.26$ nm. If density = 2.14 g/ ml, the value of 'x' is [Tl = 207, Al = 27, $(1.26)^3 = 2$]

6. The density of diamond is $2\sqrt{3}$ g/cm^3 at 25°C. The carbon-carbon bond distance (in pm) in diamond is [$(1.55)^3 = 3.75$]

7. You are given marble of diameter 10 mm. They are to be placed such that their centres are lying in a square bond by four lines each of length 40 mm. The maximum number of marbles which may be placed inside this area is

8. The edge length of the unit of LiCl (NaCl-like structure) is 520 pm. Assuming that the lithium ion is small enough that the chloride ions are in contact, the ionic radius of chloride ion (in pm) is $\left(\frac{1}{\sqrt{2}} = 0.7\right)$

9. Rutile, a mineral that contains only titanium and oxygen atoms, has structure which can be described as a closest packed array of oxide ions with titanium ions in one-half of the octahedral voids. (Ti = 48)

   ab = the mass percentage of titanium in rutile.

   c = magnitude of oxidation state of titanium in rutile.

   d = 1, if the oxidation state of Ti is positive and 2 if the oxidation state of Ti is negative.

   The value of 'abcd' is

10. A solid 'AB' crystallizes as CCP for 'A' atoms and 'B' atoms occupy half of the tetrahedral voids. One litre of the crystal is doped with 1 mole atoms of 'C', some of which replace the 'B' atoms and remaining occupies new interstitial voids without affecting the dimensions of the crystal. If the density of the crystal before doping is 4.8 g/cm^3 and the density after doping is 4.795 g/cm^3, the percentage of 'C' atoms which replace 'B' atoms is (Atomic masses of A, B and C are 40, 30 and 15, respectively)

11. An ideal crystal, AB, has rock salt structure in which A^+ is occupying octahedral voids. The crystal is doped with atoms of 'C' which occupy all the tetrahedral voids without distorting the lattice. If the crystal shows defect such that the body-centred atom is missing, then the percentage of body diagonal covered by ions/atoms in the defective crystal is (Given: $\sqrt{1.5} = 29/24$)

12. A non-stoichiometric compound Fe_7S_8 consist of iron in both Fe^{2+} and Fe^{3+} forms and sulphur is present as sulphide ions. If the percentage of cation vacancies relative to Fe^{2+} ions present initially (as ideal crystal of FeS) is **'x'**, then the value of **'10x'** is

13. The density of solid argon is 1.65 g/cm^3 at −233°C. If the argon atoms are assumed to be spheres of radius 1.54×10^{-8} cm, the approximate percentage of empty space in solid argon is (Ar = 40)

14. An element (atomic mass = 125) crystallizes in simple cubic structure. If the diameter of the largest sphere which can be placed in the crystal, without disturbing the crystal, is 366 pm and the density of crystal is 'd' g/cm^3, then the value of '300 d' is

15. The structure of crystalline macromolecules may be determined by X–ray diffraction techniques using method similar to those for smaller molecules. Fully crystalline polyethylene has its chain aligned in an orthorhombic unit cell of dimensions 667 pm × 500 pm × 280 pm. There are two repeating CH_2CH_2 units per unit cell. The theoretical density of fully crystalline polyethylene (in kg/m^3) is

Answer Keys – Exercise II

Section A (Only one Correct)

1. (b) 2. (b) 3. (a) 4. (b) 5. (c) 6. (b) 7. (d) 8. (c) 9. (a) 10. (b)
11. (c) 12. (b) 13. (c) 14. (b) 15. (d) 16. (c) 17. (c) 18. (b) 19. (b) 20. (c)
21. (d) 22. (c) 23. (a) 24. (a) 25. (b) 26. (b) 27. (d) 28. (a) 29. (b) 30. (a)
31. (a) 32. (a) 33. (d) 34. (b) 35. (a) 36. (a) 37. (b) 38. (d) 39. (d) 40. (a)

Section B (One or More than one Correct)

1. (a), (c) 2. (c), (d) 3. (c), (d) 4. (a), (d)
5. (a), (b), (d) 6. (a), (b), (c), (d) 7. (a), (b), (d) 8. (c), (d)
9. (a), (c), (d) 10. (b) 11. (b), (c), (d) 12. (a), (b), (c), (d)
13. (a), (b), (c), (d) 14. (a), (b) 15. (a), (b), (d) 16. (b)
17. (b), (c) 18. (b), (c) 19. (c), (d) 20. (b), (c)
21. (a), (b), (c) 22. (a), (c) 23. (b), (c) 24. (c), (d)
25. (c), (d)

Section C

Comprehension I

1. (b) 2. (a) 3. (a) 4. (b) 5. (c)
6. (c)

Comprehension II

7. (d) 8. (a)

Comprehension III

9. (a) 10. (b) 11. (c) 12. (c)

Comprehension IV

13. (b) 14. (b)

Comprehension V

15. (a) 16. (b)

Comprehension VI

17. (b) 18. (a)

Comprehension VII

19. (a) 20. (a) 21. (c) 22. (b)

Comprehension VIII

23. (c) 24. (b) 25. (b) 26. (a)

Comprehension IX

27. (b) 28. (b) 29. (c)

Comprehension X

30. (a) 31. (b)

Comprehension XI

32. (b) 33. (d)

Comprehension XII

34. (a) 35. (b) 36. (c) 37. (d) 38. (d)

Section D (Assertion – Reason)

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

Section E (Column Match)

1. A → Q, W; B → P, U; C → R, V
2. A → Q, W; B → P, X; C → R, Z; D → S, Y

3. A → P; B → Q, R; C → Q, S, T; D → Q, R
4. A → Q; B → P; C → S; D → R
5. A → S; B → R; C → P; D → Q
6. A → P; B → Q, S; C → R
7. A → R, S; B → P, Q, R, S; C → Q
8. A → P, S; B → P, Q; C → Q; D → Q, R
9. A → P, Q, R, S; B → Q, S; C → P, R, T; D → T
10. A → P, Q, T; B → T; C → S; D → P, R
11. A → P, T; B → R; C → Q; D → S

Section F (Subjective)

Single-digit Integer Type

1. (3) 2. (4) 3. (4) 4. (4) 5. (2) 6. (1) 7. (4) 8. (5) 9. (5) 10. (2)
11. (6) 12. (8) 13. (2) 14. (2) 15. (2)

Four-digit Integer Type

1. (0143) 2. (0066) 3. (0045) 4. (0072) 5. (0012)
6. (0155) 7. (0016) 8. (0182) 9. (6041) 10. (0067)
11. (0060) 12. (0125) 13. (0062) 14. (0500) 15. (1000)