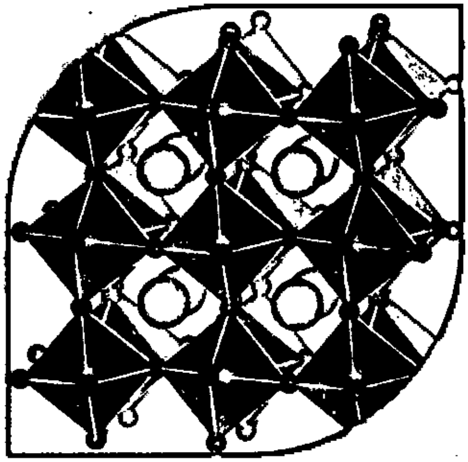


10

SOLID STATE

Types of Solid

S. No.	Crystalline solids	Amorphous solids
1.	They have a defined crystal shape.	They do not have a defined geometrical shape
2.	Long-range order	Short-range order
3.	They have sharp melting points	They do not have sharp melting points.
4.	Enthalpy of fusion is definite	Enthalpy of fusion is not definite
5.	They are hard and rigid solids.	They are comparatively soft and not very rigid.
6.	Possess definite crystal system (cubic, tetragonal, hexagonal, octahedral, etc.)	Crystal system absent ; no regular repeating unit
7.	They are true solid	They are pseudo solid
8.	They split into two pieces when cut with a sharp-edged tool ; newly generated surfaces are plain and smooth.	They cut into two pieces with irregular surfaces when cut with a sharp-edged tool.
9.	They are anisotropic (refractive index and electrical conductivity are different in different directions) (*e. g.*, NaCl, CsBr, CaF_2 and ZnS	They are isotropic. (physical properties are same in all directions) (*e. g.*, Rubber, plastic and glass)

Types of Crystalline Solids

Type of solid	Intermolecular forces	Properties	Examples
Ionic	Ion-ion forces	Brittle, hard high melting	NaCl, KCl, $MgCl_2$
Molecular	Dispersion forces/Dipole-Dipole H-bond	Soft, low melting non-conducting	H_2O, Br_2, CO_2, CH_4
Covalent network	Covalent bonds	Hard: High melting	C-Diamond, SiO_2
Metallic	Metallic bonds	Variable hardness and melting point conducting	Na, Zn, Cu, Fe

Crystal System

Crystal Systems		Bravais Lattice	Unit Cell Parameters	
			Intercepts	Crystal Angles
1.	Cubic	Primitive, face centered, body centered	$a = b = c$	$\alpha = \beta = \gamma = 90°$
2.	Orthorhombic	Primitive, face centered, body centered, end centered	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90°$
3.	Rhombohedral	Primitive	$a = b = c$	$\alpha = \beta = \gamma \neq 90°$
4.	Monoclinic	Primitive, end centered	$a \neq b \neq c$	$\alpha = \gamma = 90°, \beta \neq 90°$
5.	Triclinic	Primitive	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90°$
6.	Tetragonal	Primitive, body centered	$a = b \neq c$	$\alpha = \beta = \gamma = 90°$
7.	Hexagonal	Primitive	$a = b \neq c$	$\alpha = \beta = 90°, \gamma = 120°$

Some Formula

(i) $d = \frac{ZM}{N_0 a^3}$; (ii) Packing fraction $= \frac{Z \times V_{\text{Atom}}}{V_{\text{Unit cell}}}$; (iii) Void fraction $= 1 -$ Packing fraction ;

(iv) C.No. = No. of first neighbours
where d = density ; M = Atomic weight of element ;
N_A = Avogadro's number ; a = Edge length of cube.

Cubic System

S.No.	Property	Simple Cubic Lattice	BCC Lattice	FCC Lattice
1.	Atomic radius (r), a = edge length of cube	$r = \frac{a}{2}$	$r = \frac{a\sqrt{3}}{4}$	$r = \frac{a\sqrt{2}}{4}$
2.	No of atoms per unit cell (Z)	$Z = 1$	$Z = 2$	$Z = 4$
3.	Co-ordination No. (C.No.)	6	8	12
4.	Packing fraction (P.F.)	0.52	0.68	0.74

Types of Packing

S.No.	Property	Hexagonal close packing (HCP)	Cubic close packing (CCP)
1.	Co-ordination No. (C.No.)	12	12
2.	No. of atoms per unit cell (z)	$z = 6$	$z = 4$
3.	Packing fraction (P.F.)	P. F. = 0.74	P. F. = 0.74
4.	Type of packing	*ABAB*......	*ABCABC*......

Types of Voids

S. No.	Name of Void	$r_{\text{Void}}/r_{\text{Sphere}}$	Co-ordination Number (C.No.)
1.	Triangular void	0.155	3
2.	Tetrahedral void	0.225	4
3.	Octahedral void	0.414	6
4.	Cubic void	0.732	8

Radius Ratio

S.No.	Limiting radius ratio $\left(\frac{r_{\text{cation}}}{r_{\text{anion}}}\right)$	C.No.	Shape
1.	< 0.155	2	Linear
2.	0.155 — 0.225	3	Planar triangle
3.	0.225 — 0.414	4	Tetrahedral
4.	0.414 — 0.732	6	Octahedral
5.	0.732 — 0.999	8	Like body central cubic

Types of Ionic Structure

S.No.	Name of Structure	Location of Particle
1.	Rock salt (AB) NaCl	B^- : ccp lattice ; A^+ : Octahedral void
2.	Zinc blende (ZnS)	S^{2-} : ccp lattice ; Zn^{2+} : Alternate tetrahedral void
3.	CsCl	Cs^+ : Cube centre ; Cl^- : Corner of cube
4.	Fluorite structure (CaF_2)	Ca^{2+} : fcc lattice ; F^- : Tetrahedral void
5.	Antifluorite structure Na_2O	O^{2-} : fcc lattice ; Na^+ : Tetrahedral void

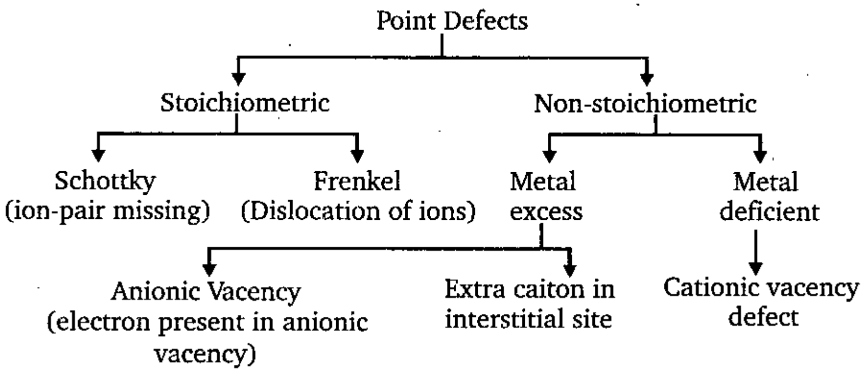
Bragg's Equation

$2d \sin\theta = n\lambda$

$n = 1$ First order reflection ; $n = 2$ Second order reflection ; θ = angle of reflection.

d = distance between planes ; λ = wavelength of x-ray

Defects



(1) Stoichiometric defects

- **Vacancy:** When constituent particle missing, then vacancy defects occurs.
- **Frenkel :** The defect in which an ion is displaced from its regular position to an interstitial position creating a vacancy. Such defect is known as frenkel defects or dislocation defect.
- **Schottky :** Defect in which a pair of one cation and one anion of equal valence is missing from an ionic crystal leading to a pair of vacant sites. Such defect is known as schottky defect.

(2) Non-Stoichiometric defects :

- **Metal excess defect :** The defect occurs due to anionic vacancies or due to the presence of extra cations at the interstitial site.
- **Metal deficiency defect :** The defect occurs due to absence of positive ions from lattice site or extra interstitial negative ions.

Electrical Properties

The solids can be **conductors, insulators** or **semiconductors.**

- Conductors conduct electricity through movement of electrons (metals) or ions (electrolytes).
- The atomic orbitals of metals form molecular orbitals which are so close in energy that they form bands. If the gap between the filled valence band the next higher unoccupied conduction band overlaps, the electrons can jump and are called conductors. If this gap is more, the electrons can not jump and the substance behaves as an insulator.
- In semiconductors, this gap is small. For example, silicon and germanium. Their conductivity can be increased by adding impurity (doping) which can be electron rich or electron deficient.
- When increase in conductivity is due to the electron-rich impurity, it is called n-type semiconductor.
- When the increase in conductivity is due to electron-deficient impurity, the conductors are called *p*-type semiconductors.

Magnetic Properties

- **Paramagnetic :** Substance weakly attracted in magnetic field and magnetized in same direction is known as paramagnetic substance.
- **Diamagnetic :** Substance weakly repelled in magnetic field is known as diamagnetic substance
- **Ferromagnetic :** Substance attracted very strongly by magnetic field is known as ferromagnetic substance.
- **Antiferromagnetic :** Substance in which oppositely located domains cancel out each other's magnetic moment is known as Antiferromagnetic substance.
- **Ferrimagnetic :** Substance in which magnetic moment of domains are arranged in parallel and antiparallel directions in unequal numbers is known as ferrimagnetic substance.

Level 1

1. Which of the following statement is true for ionic solids?
   (a) Ionic solids are soluble in non-polar solvent
   (b) Under the electric field cations and anions acquire translatory motion in opposite directions
   (c) Structural units have strong electrostatic force of attraction
   (d) Structural units have dipole-dipole interactions
2. Which one is called pseudo solid ?
   (a) CaF_2 (b) Glass (c) NaCl (d) All
3. Solids which do not show the same physical properties in different directions are called:
   (a) Pseudo solids (b) Isotropic solids
   (c) Polymorphic solids (d) Anisotropic solids
4. Graphite is an example of :
   (a) Ionic solid (b) Covalent solid
   (c) vander Waals' crystal (d) Metallic crystal
5. Amorphous solids are:
   (a) isotropic and supercooled liquids (b) anisotropic and supercooled liquids
   (c) isoenthalpic and superheated liquids (d) isotropic and superheated solids
6. Crystals which are good conductor of electricity and heat are known as :
   (a) Ionic crystals (b) Covalent crystals
   (c) Metallic crystals (d) Molecular crystals
7. The bond length and bond angles in molecules in the solid state are calculated by:
   (a) X-ray diffraction technique (b) neutrons bombardment
   (c) protons bombardment (d) none of these
8. The unit cell with parameters $\alpha = \beta = \gamma = 90°$ and $a = b \neq c$ is :
   (a) Cubic (b) Triclinic (c) Hexagonal (d) Tetragonal
9. Triclinic crystal has the following unit cell parameters :
   (a) $a = b = c; \alpha = \beta = \gamma = 90°$ (b) $a = b \neq c; \alpha = \beta = \gamma = 90°$
   (c) $a \neq b \neq c; \alpha \neq \beta \neq \gamma \neq 90°$ (d) $a = b \neq c; \alpha = \beta = 90°, \gamma = 120°$
10. If all three interfacial angles defining the unit cell, are equal in magnitude, the crystal cannot be:
    (a) rhombohedral (b) cubic (c) hexagonal (d) tetragonal
11. In a Hexagonal crystal :
    (a) $\alpha = \beta = \gamma \neq 90°; a = b = c$ (b) $\alpha = \beta = \gamma = 90°; a = b \neq c$
    (c) $\alpha = \beta = \gamma = 90°; a \neq b \neq c$ (d) $\alpha = \beta = 90°, \gamma = 120°; a = b \neq c$
12. Orthorhombic crystal has the following unit cell parameters :
    (a) $a = b = c; \alpha = \beta = \gamma = 90°$ (b) $a = b \neq c; \alpha = \beta = \gamma = 90°$
    (c) $a \neq b \neq c; \alpha = \beta = \gamma = 90°$ (d) $a = b \neq c; \alpha = \beta = 90°, \gamma = 120°$
13. Which of the crystal systems contains the maximum number of Bravais lattices?
    (a) Cubic (b) Hexagonal (c) Triclinic (d) Orthorhombic

14. The most unsymmetrical and symmetrical systems are, respectively :
(a) Tetragonal, Cubic (b) Triclinic , Cubic
(c) Rhombohedral, Hexagonal (d) Orthorhombic, Cubic

15. The crystal system of a compound with unit cell parameters,
$a = 0.328\,\text{nm}$, $b = 0.328\,\text{nm}$, $c = 0.527\,\text{nm}$ and $\alpha = \beta = \gamma = 90°$ is :
(a) Cubic (b) Tetragonal (c) Monoclinic (d) Rhombohedral

16. In the primitive cubic unit cell, the atoms are present at the:
(a) corners of the unit cell (b) centre of the unit cell
(c) centre of each face of the unit cell (d) one set of faces of the unit cell

17. In the body centered unit cell, the lattice points are present at the:
(a) corners of unit cell only
(b) corners and centre of unit cell
(c) corners and centre of each face of the unit cell
(d) corners and at one set of faces of unit cell

18. In the face centered unit cell, the lattice points are present at the:
(a) corners of unit cell only (b) corners and centre of the unit cell
(c) corners and face centres of the unit cell (d) face centres of the unit cell

19. The effective number of atoms per unit cell in a simple cube, face centred cube and body centred cube are respectively:
(a) 1, 4, 2 (b) 1, 2, 4 (c) 8, 14, 9 (d) 8, 4, 2

20. What would be the effective number of atoms per unit cell in end centered cubic unit cell, if this type of unit cell exist in nature ?
(a) 1 (b) 2 (c) 3 (d) 4

21. In the body centered cubic unit cell and simple cubic unit cell, the radius of atom in terms of edge length (A) of the unit cell is respectively:
(a) $\frac{a}{2}, \frac{a}{2\sqrt{2}}$ (b) $\frac{a}{\sqrt{2}}, \frac{a}{2}$ (c) $\frac{a}{2\sqrt{2}}, \frac{a}{2}$ (d) $\frac{\sqrt{3}a}{4}, \frac{a}{2}$

22. In the face centered cubic unit cell, the radius of atoms in terms of edge length (a) of unit cell is:
(a) $a/2$ (b) $a/\sqrt{2}$ (c) $a/2\sqrt{2}$ (d) $\sqrt{3}a/4$

23. The fraction of volume occupied by atoms in a primitive cubic unit cell is nearly:
(a) 0.48 (b) 0.52 (c) 0.55 (d) 0.68

24. The fraction of volume occupied by atoms in a body centered cubic unit cell is:
(a) 0.32 (b) 0.48 (c) 0.68 (d) 0.74

25. The fraction of volume occupied by atoms in a face centered cubic unit cell is:
(a) 0.32 (b) 0.48 (c) 0.68 (d) 0.74

26. Which of the following crystal lattice has the minimum empty space?
(a) Simple cubic (b) Body centred cubic
(c) Face centred cubic (d) Simple tetragonal

27. Which of the following has the smallest packing efficiency for atoms of a single type?
(a) Body centered cubic (b) Face centered cubic
(c) Simple cubic (d) None of these

28. Polonium crystallizes in a simple cubic structure. The edge of the unit cell is 0.236 nm. What is the radius of the polonium atom:
(a) 0.144 nm (b) 0.156 nm (c) 0.118 nm (d) 0.102 nm

29. Lithium crystallizes as body centered cubic crystals. If the length of the side of unit cell is 350 pm, the atomic radius of lithium is:
(a) 303.1 pm (b) 606.2 pm (c) 151.5 pm (d) 123.7 pm

30. Gold has a face centered cubic lattice with an edge length of the unit cube of 407 pm. The diameter of the gold atom is:
(a) 576.6 pm (b) 287.8 pm (c) 352.5 pm (d) 704.9 pm

31. The neon atoms has a radius of 160 pm. What is the edge of the unit cell of a face centered structure of neon?
(a) 490 pm (b) 320 pm (c) 453 pm (d) 481 pm

32. What are the number of atoms per unit cell and the number of nearest neighbours in a simple cubic structure?
(a) 1, 6 (b) 4, 12 (c) 2, 8 (d) 2, 6

33. What are the number of atoms per unit cell and the number of nearest neighbours in a face centered cubic structure?
(a) 4, 8 (b) 2, 8 (c) 2, 6 (d) 4, 12

34. What are the number of atoms per unit cell and the number of nearest neighbours in a body centered cubic structure?
(a) 4, 12 (b) 1, 6 (c) 2, 8 (d) 2, 5

35. Each edge of a cubic unit cell is 400 pm long. If atomic weight of the element is 120 and it's density is 6.25 g/cm^3. The crystal lattice is : (use $N_A = 6 \times 10^{23}$)
(a) primitive (b) body centered (c) face centered (d) end centered

36. Tungsten has an atomic radius of 0.136 nm. The density of tungsten is 19.4 g/cm^3. What is the crystal structure of tungsten? (Atomic weight: $W = 184$)
(a) Simple cubic (b) Body centered cubic
(c) Face centered cubic (d) None of these

37. The density of argon (face centered cubic cell) is 1.83 g/cm^3 at 20°C. What is the length of an edge a unit cell? (Atomic weight : Ar = 40)
(a) 0.599 nm (b) 0.569 nm (c) 0.525 nm (d) 0.551 nm

38. The density of nickel (face centered cubic cell) is 8.94 g/cm^3 at 20°C. What is the diameter of the atom? (Atomic weight: Ni = 59)
(a) 0.124 nm (b) 0.136 nm (c) 0.149 nm (d) 0.110 pm

39. The density of krypton (face centered cubic cell) is 3.19 g/cm^3. What is the radius of the atom? (Atomic weight: Kr = 84)
(a) 0.198 nm (b) 0.221 nm (c) 0.206 nm (d) 0.225 nm

40. The face centered cubic cell of platinum has a length of 0.392 nm. Calculate the density of platinum (g/cm^3) : (Atomic weight : Pt = 195)
(a) 20.9 (b) 20.4 (c) 19.6 (d) 21.5

41. The body centered cubic cell of chromium has a length of 0.288 nm. Calculate the density of chromium (g/cm^3) : (Atomic weight : Cr = 52.0)
(a) 6.80 (b) 7.60 (c) 6.60 (d) 7.23

42. An element crystallizes in a face centered cubic lattice and the edge of the unit cell is 0.559 nm. The density is 3.19 g/cm^3. What is the atomic weight?
(a) 87.6 (b) 79.9 (c) 85.5 (d) 83.9

43. The element crystallizes in a body centered cubic lattice and the edge of the unit cell is 0.351 nm. The density is 0.533 g/cm^3. What is the atomic weight?
(a) 12.0 (b) 6.94 (c) 9.01 (d) 10.8

44. An element X (At. wt. = 80 g/mol) having fcc structure, calculate no. of unit cells in 8 gm of X:
(a) $0.4 \times N_A$ (b) $0.1 \times N_A$ (c) $4 \times N_A$ (d) none of these

45. Molybdenum (At. wt. = 96 g mol^{-1}) crystallizes as bcc crystal. If density of crystal is 10.3 g/cm^3, then radius of Mo atom is (use $N_A = 6 \times 10^{23}$):
(a) 111 pm (b) 314 pm (c) 135.96 pm (d) none of these

46. What is the coordination number of an atom for an element crystallizing with a cubic lattice? Calculate the corresponding coordination number for the simple, fcc and bcc lattices:
(a) 12 sc; 12 fcc; 8 bcc (b) 6 sc; 14 fcc; 8 bcc
(c) 8 sc; 12 fcc; 6 bcc (d) 6 sc; 12 fcc; 8 bcc

47. Which of the following layering pattern will have a void fraction of 0.260?
(a) ABCCBAABC (b) ABBAABBA (c) ABCABCABC (d) ABCAABCA

48. The most malleable metals (Cu, Ag, Au) have close-packing of the type :
(a) Hexagonal close-packing
(b) Cubic close-packing
(c) Body-centred cubic packing
(d) Malleability is not related to type of packing

49. The co-ordination number of a metal crystallising in a hexagonal close-packed structure is:
(a) 12 (b) 4 (c) 8 (d) 6

50. If the ratio of coordination no. of A to that of B is $x : y$, then the ratio of no. of atoms of A to that no. of atoms of B in unit cell is:
(a) $x : y$ (b) $y : x$ (c) $x^2 : y$ (d) $y : x^2$

51. The atomic radius of strontium (Sr) is 215 pm and it crystallizes with a cubic closest packing. Edge length of the cube is:
(a) 430 pm (b) 608.2 pm (c) 496.53 pm (d) none of these

52. By X-ray diffraction it is found that nickel (at mass = 59 g mol^{-1}), crystallizes with ccp. The edge length of the unit cell is 3.5 Å. If density of Ni crystal is 9.0 g/cm^3. Then value of Avogadro's number from the data is :
(a) 6.05×10^{23} (b) 6.11×10^{23} (c) 6.02×10^{23} (d) 6.023×10^{23}

53. Stacking of square close packed layers give rise to:
(a) bcc structure (b) fcc structure
(c) Simple cubic structure (d) hcp structure

54. In a hexagonal close packed (hcp) structure of spheres, the fraction of the volume occupied by the sphere is A. In a cubic close packed structure the fraction is B. The relation for A and B is :
(a) $A = B$
(b) $A < B$
(c) $A > B$
(d) A is equal to the fraction in a simple cubic lattice.

55. The unit cell present in ABCABC, closest packing of atoms is:
(a) hexagonal
(b) tetragonal
(c) face centered cube
(d) primitive cube

56. The number of atoms present in a hexagonal close-packed unit cell is :
(a) 4
(b) 6
(c) 8
(d) 12

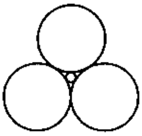
57. The unit cell present in ABAB, closest packing of atoms is:
(a) hexagonal
(b) tetragonal
(c) face centered cube
(d) primitive cube

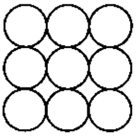
58. The numbers of tetrahedral and octahedral holes in a hexagonal primitive unit cell are :
(a) 8, 4
(b) 6, 12
(c) 2, 1
(d) 12, 6

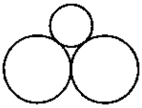
59. Which one of the following schemes of ordering closed packed sheets of equal sized spheres do not generate closest packed lattice?
(a) ABCABC
(b) ABACABAC
(c) ABBAABBA
(d) ABCBCABCBC

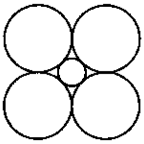
60. In the closest packing of atoms, there are:
(a) one tetrahedral void and two octahedral voids per atom
(b) two tetrahedral voids and one octahedral void per atom
(c) two of each tetrahedral and octahedral voids per atom
(d) one of each tetrahedral and octahedral void per atom

61. Which of the following figures represents the cross-section of an octahedral site?

(a) 

(b) 

(c) 

(d) 

62. In which of the following pairs of structures, tetrahedral as well as octahedral holes are found?
(a) bcc and fcc
(b) hcp and simple cubic
(c) hcp and ccp
(d) bcc and hcp

63. The number of octahedral void in bcc structure is :
(a) 0
(b) 1
(c) 2
(d) 4

64. An ionic compound is expected to have octahedral structure if r_c/r_a $(r_c < r_a)$ lies in the range of:
(a) 0.414 to 0.732
(b) 0.732 to 0.82
(c) 0.225 to 0.414
(d) 0.155 to 0.225

65. An ionic compound is expected to have tetrahedral structure if r_c/r_a:
(a) lies in the range of 0.414 to 0.732
(b) lies in the range of 0.225 to 0.414
(c) lies in the range of 0.155 to 0.225
(d) is more than 0.732

66. An ionic compound is expected to have body centered type cubic unit cell if r_c/r_a:
(a) is greater than 0.732
(b) lies in the range of 0.414 to 0.732
(c) lies in the range of 0.255 to 0.414
(d) lies in the range of 0.155 to 0.225

67. In the closest packing of atoms A (radius : r_a), the radius of atom B that can be fitted into tetrahedral void is:
(a) $0.155\ r_a$
(b) $0.225\ r_a$
(c) $0.414\ r_a$
(d) $0.732\ r_a$

68. In the closest packing of atoms *A* (radius : r_a), the radius of atom *B* that can be fitted octahedral void is:
(a) $1.155\ r_a$ (b) $0.225\ r_a$ (c) $0.414\ r_a$ (d) $0.732\ r_a$

69. How many nearest neighbours are there in an atom or ion for an octahedral hole of a closed packed structure?
(a) 4 (b) 6 (c) 8 (d) 12

70. How many "nearest" and "next nearest" neighbours, respectively, does potassium have in bcc lattice ?
(a) 8, 8 (b) 8, 6 (c) 6, 8 (d) 6, 6

71. In the closest packing of atoms:
(a) the size of tetrahedral void is greater than that of octahedral void
(b) the size of tetrahedral void is smaller than that of octahedral void
(c) the size of tetrahedral void is equal to that of octahedral void
(d) the size of tetrahedral void may be greater or smaller or equal to that of octahedral void depending upon the size of atoms

72. In the ionic compound *AB* the ratio $r_{A^+} : r_{B^-}$ is 0.414. Indicate the correct statement of the following:
(a) Cations form close packing and anions exactly fit into the octahedral voids
(b) Anions form close packing and cations occupy precisely half of the tetrahedral voids
(c) Anions form close packing and cations occupy precisely all the octahedral voids
(d) Anions form close packing and cations fit into the octahedral voids loosely

73. In the unit cell of KCl (NaCl type), Cl^- ions constitute ccp and K^+ ions fall into the octahedral holes. These holes are:
(a) one at the centre and 6 at the centres of the faces
(b) one at the centre and 12 at the centres of the edges
(c) 8 at the centres of 8 small cubes forming the unit cell
(d) none of these

74. Which is incorrect statement ?
(a) In NaCl structure, tetrahedral voids are unoccupied
(b) In ZnS structure, octahedral voids are unoccupied
(c) In CaF_2 structure, all tetrahedral voids are occupied
(d) In Na_2O structure, all tetrahedral voids are unoccupied

75. If the radius of the anion in an ionic solid is 200 pm, what would be the radius of the cation that fits exactly into a cubic hole?
(a) 146.4 pm (b) 82.8 pm (c) 45 pm (d) None of these

76. The CsCl type structure is exhibited by alkali halides only when the radius of the cation is large enough to keep touching its eight nearest neighbour anions. Below what minimum ratio of cation to anion radii (r^+/r^-) this contact is prevented?
(a) 0.225 (b) 0.414
(c) 0.632 (d) 0.732

77. MgO crystallizes in a cubic type crystal system. The ionic radii for Mg^{2+} and O^{2-} are 0.066 and 0.140 nm respectively. One can conclude that the Mg^{2+} ions occupy:
(a) a cubic hole in a simple cubic structure
(b) every tetrahedral hole in a close packed structure

(c) an octahedral hole in a cubic close packed structure
(d) every other tetrahedral hole in a close packed structure

78. The unit cell of diamond is made up of:
(a) 6 carbon atoms, 4 atoms constitute ccp and two atoms occupy half of octahedral voids
(b) 8 carbon atom, 4 atoms constitute ccp and 4 atoms occupy all the octahedral voids
(c) 8 carbon atoms, 4 atoms form fcc lattice and 4 atoms occupy half of the tetrahedral voids alternately
(d) 12 carbon atoms, 4 atoms form fcc lattice and 8 atoms occupy all the tetrahedral holes

79. 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

80. Predict coordination number of the cation in crystals of the following compounds:
1. MgO : $r_c = 0.65$ Å; $r_a = 1.40$ Å, 2. MgS : $r_c = 0.65$ Å; $r_a = 1.84$ Å
(a) 6, 4 (b) 4, 6 (c) 3, 4 (d) 6, 8

81. In a cubic unit cell, seven of the eight corners are occupied by atoms A and centres of faces are occupied by atoms B. The general formula of the compound is :
(a) A_7B_6 (b) A_7B_{12} (c) A_7B_{24} (d) $A_{24}B_7$

82. CaS exists in a cubic close packed arrangement of S^{2-} ions in which Ca^{2+} ions occupy 1/2 of the available tetrahedral holes. How many Ca^{2+} and S^{2-} ions are contained in the unit cell?
(a) 1, 1 (b) 2, 4 (c) 4, 4 (d) 4, 2

83. In the spinel structure, oxides ions are cubical-closest packed whereas 1/8th of tetrahedral voids are occupied by A^{2+} cation and 1/2 of octahedral voids are occupied by B^{3+} cations. The general formula of the compound having spinel structure is:
(a) $A_2B_2O_4$ (b) AB_2O_4 (c) $A_2B_4O_2$ (d) $A_4B_2O_2$

84. If the anions (A) from hexagonal closest packing and cations (C) occupy only 2/3 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

85. In a solid, oxide ions are arranged in ccp, cations A occupy $(1/8)^{th}$ of the tetrahedral voids and cations B occupy $(1/4)^{th}$ of the octahedral voids. The formula of the compound is:
(a) ABO_4 (b) AB_2O_3 (c) A_2BO_4 (d) AB_4O_4

86. In a face centered cubic arrangement of A and B atoms whose A atoms are at the corner of the unit cell and B atoms at the face centers. One of the B atoms missing from one of the face in unit cell. The simplest formula of compound is:
(a) AB_3 (b) A_8B_5 (c) A_2B_5 (d) $AB_{2/5}$

87. An alloy of copper, silver and gold is found to have copper constituting the ccp lattice. If silver atoms occupy the edge centres and gold is present at body centre, the alloy will have the formula:
(a) Cu_4Ag_2Au (b) Cu_4Ag_4Au (c) Cu_4Ag_3Au (d) CuAgAu

88. Which of the following statements is correct in the rock-salt structure of an ionic compound?
(a) Co-ordination number of cation is four and anion is six
(b) Co-ordination number of cation is six and anion is four
(c) Co-ordination number of each cation and anion is four
(d) Co-ordination number of each cation and anion is six

89. Which of the following statements is correct in the body centered type cubic structure of an ionic compound?
(a) Co-ordination number of each cation and anion is two
(b) Co-ordination number of each cation and anion is four
(c) Co-ordination number of each cation and anion is six
(d) Co-ordination number of each cation and anion is eight

90. Which of the following statements is correct in the zinc blende type structure of an ionic compound?
(a) Co-ordination number of each cation and anion is two
(b) Co-ordination number of each cation and anion is four
(c) Co-ordination number of each cation and anion is six
(d) Co-ordination number of each cation and anion is eight

91. Which of the following expression is correct in case of a sodium chloride unit cell (edge length, a)?
(a) $r_c + r_a = a$ (b) $r_c + r_a = a/2$
(c) $r_c + r_a = 2a$ (d) $r_c + r_a = \sqrt{2}a$

92. In an ideal closest rock salt structure (edge length, a), which of the following expressions is correct?
(a) $r_a = \sqrt{2}a$ (b) $r_a = a/\sqrt{2}$
(c) $r_a = a/2\sqrt{2}$ (d) $r_a = a/4$

93. Which of the following expressions is correct in case of a CsCl unit cell (edge length, a)?
(a) $r_c + r_a = a$ (b) $r_c + r_a = a/\sqrt{2}$
(c) $r_c + r_a = \sqrt{3}a/2$ (d) $r_c + r_a = a/2$

94. In NaCl the centres of two nearest like-charged ions are present at a distance of:
(a) $\frac{1}{2}a\sqrt{2}$ (b) $\frac{1}{2}a$
(c) $\frac{\sqrt{3}}{2}a$ (d) $\frac{1}{\sqrt{2}}2a$

95. In sodium chloride crystal, the number of next nearest neighbours of each Na^+ ions is:
(a) 8 Cl^- ions (b) 12 Na^+ ions
(c) 12 Cl^- ions (d) 24 Cl^- ions

96. In an ionic compound A^+X^-, the radii of A^+ and X^- ions are 1.0 pm and 2.0 pm, respectively. The volume of the unit cell of the crystal AX will be :
(a) 27 pm^3 (b) 64 pm^3
(c) 125 pm^3 (d) 216 pm^3

97. The coordination number of cation and anion in fluorite CaF_2 and anti-fluorite Na_2O are respectively:

(a) 8 : 4 and 6 : 3 (b) 6 : 3 and 4 : 4

(c) 8 : 4 and 4 : 8 (d) 4 : 8 and 8 : 4

98. Select the incorrect statement in a CsCl crystal:

(a) Cs^+ forms a simple cubic lattice, Cl^- forms a simple cubic lattice

(b) Cl^- occupies body centre of Cs^+

(c) Cs^+ occupies body centre of Cl^-

(d) It is impossible for Cl^- to occupy body centre of Cs^+ because the body centre void of Cs^+ is smaller than Cl^- ion size

99. The radius of a divalent cation A^{2+} is 94 pm and of divalent anion B^{2-} is 146 pm. The compound *AB* has :

(a) Rock salt structure (b) Zinc blende structure

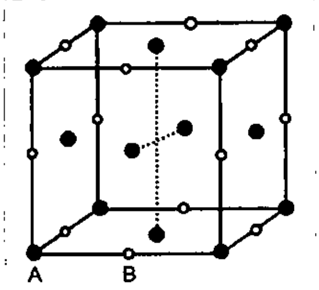
(c) Antifluorite structure (d) Caesium chloride like structure

100. A binary solid (*AB*) has a rock salt structure. If the edge length is 400 pm, and radius of cation is 80 pm the radius of anion is:

(a) 100 pm (b) 120 pm

(c) 250 pm (d) 325 pm

101. For a solid with the structure shown in Fig., the coordination numbers of the points A and B, respectively, are



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

102. An ionic compound *AB* has fluorite type structures. If the radius B^- is 200 pm, then the ideal radius of A^+ would be:

(a) 82.8 pm (b) 146.4 pm (c) 40 pm (d) 45 pm

103. In which of the following structures, the anion has maximum coordination number ?

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

104. CsCl has bcc structure with Cs^+ at the centre and Cl^- ion at each corner. If r_{Cs^+} is 1.69 Å and r_{Cl^-} is 1.81 Å, what is the edge length of the cube?

(a) 3.50 Å (b) 3.80 Å

(c) 4.04 Å (d) 4.50 Å

105. CsBr has bcc type structure with edge length 4.3 pm. The shortest inter ionic distance in between Cs^+ and Br^- is:

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

106. If the radius of Cl^- ion is 181 pm, and the radius of Na^+ ion is 101 pm then the edge length of unit cell is:

(a) 282 pm (b) 285.71 pm
(c) 512 pm (d) 564 pm

107. Ammonium chloride crystallizes in a body centered cubic lattice with edge length of unit cell equal to 387 pm. If the size of Cl^- ion is 181 pm, the size of NH_4^+ ion would be:

(a) 116 pm (b) 154 pm
(c) 174 pm (d) 206 pm

108. Salt *AB* has a zinc blende structure. The radius of A^{2+} and B^{2-} ions are 0.7 Å and 1.8 Å respectively. The edge length of *AB* unit cell is:

(a) 2.5 Å (b) 5.09 Å
(c) 5 Å (d) 5.77 Å

109. Transition metals, when they form interstitial compounds, the non-metals (H, B, C, N) are accomodated in :

(a) Voids or holes in cubic-packed structure (b) Tetrahedral voids
(c) Octahedral voids (d) All of these

110. In diamond, each carbon atom is bonded to four other carbon atoms tetrahedrally. Alternate tetrahedral void occupied by carbon atoms. The number of carbon atoms per unit cell is :

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

111. Which of the following statements for crystals having Schottky defect is not correct?

(a) Schottky defect arises due to the absence of a cation and anion from the position which it is expected to occupy
(b) Schottky defect are more common in ionic compounds with high co-ordination numbers
(c) The density of the crystals having Schottky defect is larger than that of the perfect crystal
(d) The crystal having Schottky defect is electrical neutral as a whole

112. Which is correct statement ?

(a) When temperature increases then number of defects decreases.
(b) Schottky defect occurs when radius of cation is smaller
(c) Frenkel defect occurs when radius of cation is smaller
(d) None of these

113. Which of the following statements for crystals having Frenkel defect is not correct?

(a) Frenkel defects are observed where the difference in sizes of cations and anions is large
(b) The density of crystals having Frenkel defect is lesser than that of a pure perfect crystal
(c) In an ionic crystal having Frenkel defect may also contain Schottky defect
(d) Usually alkali halides do not have Frenkel defect

114. When anion leaves the normal lattice site and electron occupies interstitial sites in its crystal lattice, it is called:

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

115. Which of the following defects does KBr show?

(a) Frenkel (b) Schottky
(c) Metal excess (d) Metal deficiency

116. Dopping of AgCl crystals with $CdCl_2$ results in:
(a) Schottky defect (b) Frenkel defect
(c) Substitutional cation vacancy (d) Formation of F-centres

117. 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

118. Which one of the following crystals does not exhibit Frenkel defect?
(a) AgBr (b) AgCl
(c) CsCl (d) ZnS

119. Select the incorrect statement:
(a) Stoichiometry of crystal remains uneffected due to Schottky defect
(b) Frenkel defect is usually shown by ionic compounds having low coordination number
(c) F-centres generation is responsible factor for imparting the colour to the crystal
(d) Density of crystal always increases due to substitutional impurity defect

120. In diamond, carbon atom occupy fcc lattice points as well as alternate tetrahedral voids. If edge length of the unit cell is 356 pm, then diameter of carbon atom is:
(a) 77.07 pm (b) 154.14 pm
(c) 251.7 pm (d) 89 pm

121. When NaCl is dopped with 10^{-5} mole % of $SrCl_2$, what is the no. of cationic vacancies?
(a) $10^{-5} \times N_A$ (b) $10^{-7} \times N_A$
(c) $2 \times 10^{-7} N_A$ (d) None of these

122. The composition of a sample of Wustite is $Fe_{0.93}O$. What is the percentage of iron present as Fe^{3+} in total iron?
(a) 15.05% (b) 25%
(c) 35% (d) 45%

123. A certain sample of cuprous sulphide is found to have composition $Cu_{1.8}S$, because of incorporation of Cu^{2+} ions in the lattice. What is the mole % of Cu^{2+} in total copper content in this crystal?
(a) 99.8% (b) 11.11%
(c) 88.88% (d) None of these

124. Ferrimagnetism is in :
(a) ↑↑↑↑↑ (b) ↑↓↑↓
(c) ↑↑↑↓↓ (d) none of these

125. Fe_3O_4 is ferrimagnetic at room temperature but at 850 K it becomes :
(a) diamagnetic (b) ferromagnetic
(c) non-magnetic (d) paramagnetic

Level 2

1. When heated above 916°C, iron changes its bcc crystalline form to fcc without the change in the radius of atom. The ratio of density of the crystal before heating and after heating is:
(a) 1.069 (b) 0.918 (c) 0.725 (d) 1.231

2. $TlAl(SO_4)_2 \cdot xH_2O$ is bcc with 'a' = 1.22 nm. If the density of the solid is 2.32 g/cc, then the value of x is (Given : $N_A = 6 \times 10^{23}$; at. wt. : Tl = 204, Al = 27, S = 32).
(a) 2 (b) 4 (c) 47 (d) 70

3. In an atomic bcc, what fraction of edge is not covered by atoms?
(a) 0.32 (b) 0.16 (c) 0.134 (d) 0.268

4. The packing efficiency of a simple cubic crystal with an interstitial atom exactly fitting at the body center is:
(a) 0.48 (b) 0.52 (c) 0.73 (d) 0.91

5. An atomic solid crystallizes in a body centre cubic lattice and the inner surface of the atoms at the adjacent corner are separated by 60.3 pm. If the atomic weight of A is 48, then density of the solid, is nearly:
(a) 2.7 g/cc (b) 5.07 g/cc (c) 3.5 g/cc (d) 1.75 g/cc

6. Sodium (Na = 23) crystallizes in bcc arrangement with the interfacial separation between the atoms at the edge 53.6 pm. The density of sodium crystal is:
(a) 2.07 g/cc (b) 2.46 g/cc (c) 1.19 g/cc (d) none of these

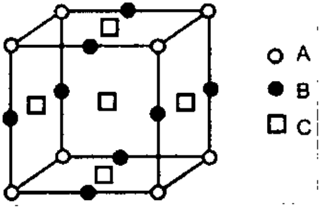
7. The density of solid argon (Ar = 40 g/mol) is 1.68 g/mL at 40 K. If the argon atom is assumed to be a sphere of radius 1.50×10^{-8} cm, what % of solid Ar is apparently empty space?
(use $N_A = 6 \times 10^{23}$)
(a) 35.64 (b) 64.36 (c) 74% (d) none of these

8. A body centered cubic lattice is made up of hollow spheres of B. Spheres of solid A are present in hollow spheres of B. Radius of A is half of radius of B. What is the ratio of total volume of spheres of B unoccupied by A in a unit cell and volume of unit cell?
(a) $\frac{7\sqrt{3}\pi}{64}$ (b) $\frac{7\sqrt{3}}{128}$ (c) $\frac{7.\pi}{24}$ (d) none of these

9. First three nearest neighbour distances for primitive cubic lattice are respectively (edge length of unit cell = a):
(a) $a, \sqrt{2}a, \sqrt{3}a$ (b) $\sqrt{3}a, \sqrt{2}a, a$ (c) $a, \sqrt{2}a, 2a$ (d) $a, \sqrt{3}a, 2a$

10. First three nearest neighbour distances for body centered cubic lattice are respectively:
(a) $\sqrt{2}a, a, \sqrt{3}a$ (b) $\frac{a}{\sqrt{2}}, a, \sqrt{3}a$ (c) $\frac{\sqrt{3}a}{2}, a, \sqrt{2}a$ (d) $\frac{\sqrt{3}a}{2}, a, \sqrt{3}a$

11. Given : The unit cell structure of compound is shown below.



The formula of compound is :

(a) $A_8B_{12}C_5$ (b) AB_2C_3 (c) $A_2B_2C_5$ (d) ABC_5

12. The density of a pure substance 'A' whose atoms are in cubic close pack arrangement is 1 g/cc. If all the tetrahedral voids are occupied by 'B' atom, what is the density of resulting solid in g/cc. [Atomic mass $(A) = 30$ g/mol and atomic mass $(B) = 50$ g/mol]

(a) 3.33 (b) 4.33 (c) 2.33 (d) 5.33

13. In a planar tetra-atomic molecule, XY_3, X is at the centroid of the equilateral triangle formed by the atoms, Y. If the X—Y bond distance is 1 Å, what is the distance between the centres of any two Y atoms?

(a) $1/\sqrt{3}$ Å (b) $\sqrt{2}$ Å

(c) $\sqrt{3}$ Å (d) $1/\sqrt{2}$ Å

14. How many unit cells are present in 5.0 gm of crystal AB (formula mass of $AB = 40$) having rock salt type structure? (N_A = Avogadro's no.)

(a) N_A (b) $\frac{N_A}{10}$

(c) $4N_A$ (d) none of these

15. The density of CaF_2 (fluorite structure) is 3.18 g/cm^3. The length of the side of the unit cell is:

(a) 253 pm (b) 344 pm

(c) 546 pm (d) 273 pm

16. A crystal of lead (II) sulphide has NaCl structure. In this crystal the shortest distance between a Pb^{2+} ion and S^{2-} ion is 297 pm. What is the volume of unit cell in lead sulphide?

(a) 209.6×10^{-24} cm^3 (b) 207.8×10^{-23} cm^3

(c) 22.3×10^{-23} cm^3 (d) 209.8×10^{-23} cm^3

17. CdO has NaCl structures with density 8.27 g/cc. If the ionic radius of O^{2-} is 1.24 Å, determine ionic radius of Cd^{2+}:

(a) 1.5 Å (b) 1.1 Å

(c) 1.9 Å (d) 1.5 Å

18. KCl crystallizes in the same type of lattice as does NaCl. Given that $r_{Na^+}/r_{Cl^-} = 0.50$ and $r_{Na^+}/r_{K^+} = 0.70$, calculate the ratio of the side of the unit cell for KCl to that for NaCl:

(a) 1.143 (b) 1.224

(c) 1.414 (d) 0.875

19. Ferrous oxide has a cubic structure and edge length of the unit cell is 5.0 Å. Assuming the density of ferrous oxide to be 3.84 g/cm^3, the no. of Fe^{2+} and O^{2-} ions present in each unit cell be : (use $N_A = 6 \times 10^{23}$) :

(a) 4 Fe^{2+} and 4 O^{2-} (b) 2 Fe^{2+} and 2 O^{2-}

(c) 1 Fe^{2+} and 1 O^{2-} (d) 3 Fe^{2+} and 4 O^{2-}

20. If an element (at. wt. = 50) crystallises in fcc lattice, with $a = 0.50$ nm. What is the density of unit cell if it contains 0.25% Schottky defects (use $N_A = 6 \times 10^{23}$)?

(a) 2.0 g/cc (b) 2.66 g/cc

(c) 3.06 g/cc (d) none of these

21. An element X (atomic weight = 24 gm/mol) forms a face centered cubic lattice. If the edge length of the lattice is 4×10^{-8} cm and the observed density is 2.40×10^{3} kg/m^{3}, then the percentage occupancy of lattice points by element X is : (Use $N_A = 6 \times 10^{23}$) :

(a) 96 (b) 98

(c) 99.9 (d) none of these

22. In fcc lattice, A, B, C, D atoms are arranged at corner, face center, octahedral void and tetrahedral void respectively, then the body diagonal contains:

(a) $2A, C, 2D$ (b) $2A, 2B, 2C$

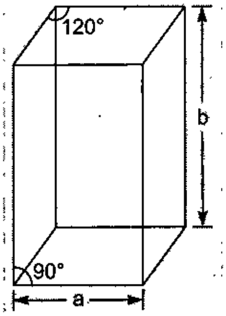
(c) $2A, 2B, D$ (d) $2A, 2D$

23. The distance between an octahedral and tetrahedral void in fcc lattice would be:

(a) $\sqrt{3}a$ (b) $\frac{\sqrt{3}a}{2}$

(c) $\frac{\sqrt{3}a}{3}$ (d) $\frac{\sqrt{3}a}{4}$

24. A_2B molecules (molar mass = 259.8 g/mol) crystallises in a hexagonal lattice as shown in figure. The lattice constants were $a = 5$ Å and $b = 8$ Å. If density of crystal is 5 g/cm^3 then how many molecules are contained in given unit cell? (use $N_A = 6 \times 10^{23}$)



(a) 6 (b) 4 (c) 3 (d) 2

25. Graphite has h.c.p. arrangements of carbon atoms and the parallel planes are 3.35 Å apart. Determine density of graphite:

(a) 2.46 g/cc (b) 0.41 g/cc (c) 1 g/cc (d) 1.41 g/cc

26. How many effective Na^+ and Cl^- ions are present respectively in a unit cell of NaCl solid (Rock salt structure) if all ions along line connecting opposite face centres are absent?

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

27. A crystal is made of particles X and Y. X forms fcc packing and Y occupies all the octahedral voids. If all the particles along one body diagonal are removed then the formula of the crystal would be:

(a) X_4Y_3 (b) X_5Y_4 (c) X_4Y_5 (d) none of these

28. Select right expression for determining Packing fraction (P. F.) of NaCl unit cell (assume ideal), if ions along an edge diagonal are absent:

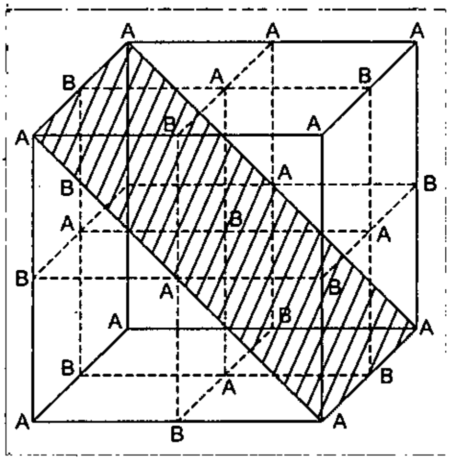
(a) $\text{P.F.} = \dfrac{\frac{4}{3}\pi(r_+^3 + r_-^3)}{16\sqrt{2}\,r_-^3}$ (b) $\text{P.F.} = \dfrac{\frac{4}{3}\pi\left(\frac{5}{2}r_+^3 + 4r_-^3\right)}{16\sqrt{2}\,r_-^3}$

(c) $\text{P.F.} = \dfrac{\frac{4}{3}\pi\left(\frac{5}{2}r_+^3 + r_-^3\right)}{16\sqrt{2}\,r_-^3}$ (d) $\text{P.F.} = \dfrac{\frac{4}{3}\pi\left(\frac{7}{2}r_+^3 + r_-^3\right)}{16\sqrt{2}\,r_-^3}$

29. A crystal is made of particles X, Y and Z. X forms fcc packing. Y occupies all the octahedral voids of X and Z occupies all the tetrahedral voids of X. If all the particles along one body diagonal are removed then the formula of the crystal would be:

(a) XYZ_2 (b) X_2YZ_2 (c) $X_8Y_4Z_5$ (d) $X_5Y_4Z_8$

30. A crystal is made of particles A and B. A forms fcc packing and B occupies all the octahedral voids. If all the particles along the plane as shown in figure are removed, then, the formula of the crystal would be:



(a) AB (b) A_5B_7 (c) A_7B_5 (d) none of these

31. In the rock salt AB, if C introduced in tetrahedral voids such that no distortion occurs. Then formula of resultant compound is :

(a) ABC (b) ABC_2 (c) A_4B_4C (d) ABC_8

32. Given length of side of hexagonal unit cell is $\frac{100}{\sqrt{2}}$ pm. The volume of hexagonal unit cell is (in pm^3) :

(a) 8×10^6 (b) 1.5×10^6 (c) 64×10^6 (d) 36×10^6

Level 3

PASSAGE 1

Packing fraction of a unit cell is defined as the fraction of the total volume of the unit cell occupied by the atom(s).

$$\text{P.F.} = \frac{\text{Volume of the atom(s) present in a unit cell}}{\text{Volume of unit cell}} = \frac{Z \times \frac{4}{3}\pi r^3}{a^3}$$

and % of empty space $= 100 - \text{P.F.} \times 100$
where Z = effective number of atoms in a cube
r = radius of an atom
a = edge length of the cube

1. % of empty space in body centered cubic unit cell is nearly:
(a) 52.36 (b) 68 (c) 32 (d) 26

2. Packing fraction in face centered cubic unit cell is:
(a) 0.7406 (b) 0.6802 (c) 0.5236 (d) None of these

PASSAGE 2

Density of a unit cell is represented as

$$\rho = \frac{\text{Effective no. of atom(s)} \times \text{Mass of a unit cell}}{\text{Volume of a unit cell}} = \frac{Z.M.}{N_A . a^3}$$

where, mass of unit cell = mass of effective no. of atom(s) or ion(s).
M = At. wt./formula wt.
N_A = Avogadro's no. $\Rightarrow 6.023 \times 10^{23}$
a = edge length of unit cell

1. Silver crystallizes in a fcc lattice and has a density of 10.6 g/cm^3. What is the length of an edge of the unit cell?
(a) 0.407 nm (b) 0.2035 nm (c) 0.101 nm (d) 4.07 nm

2. An element crystallizes in a structure having fcc unit cell of an edge 200 pm. Calculate the density, if 100 g of this element contains 12×10^{23} atoms:
(a) 41.66 g/cm^3 (b) 4.166 g/cm^3 (c) 10.25 g/cm^3 (d) 1.025 g/cm^3

3. The density of KBr is 2.75 g/cm^{-3}. The length of the edge of the unit cell is 654 pm. To which type of cubic crystal, KBr belongs?
(a) simple cubic (b) bcc (c) fcc (d) none of these

PASSAGE 3

A spinel is an important class of oxides consisting of two types of metal ions with the oxide ions arranged in ccp layers. The normal spinel has one-eighth of the tetrahedral holes occupied by one type of metal ion and one-half of the octahedral holes occupied by another type of metal ion. Such a spinel is formed by Mg^{2+}, Al^{3+} and O^{2-}. The neutrality of the crystal is being maintained.

1. The formula of the spinel is:
(a) Mg_2AlO_4 (b) $MgAl_2O_4$ (c) $Mg_3Al_2O_6$ (d) none of these

2. Type of hole occupied by Al^{3+} ions is:
(a) tetrahedral (b) octahedral (c) both (a) and (b) (d) none of these

3. Type of hole occupied by Mg^{2+} ions is:
(a) tetrahedral (b) octahedral (c) both (a) and (b) (d) none of these

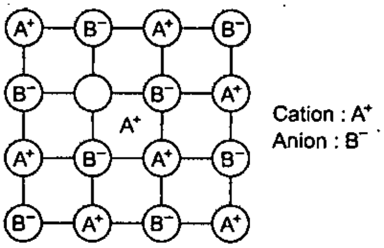
4. If oxide ion is replaced by $X^{-8/3}$, the number of anionic vacancy per unit cell is:
(a) 1 (b) 2 (c) 3 (d) 3/4

PASSAGE 4

Ionic lattice has two major points defects, (1) Schottky (2) Frenkel defects. Schottky defects occurs due to the cation-anion pair's missing from the lattice sites. Frenkel defects occurs when an ion leaves its lattice site and fits into an interstitial space. The neutrality of the crystal is being maintained and we considered all losses from interstitial positions.

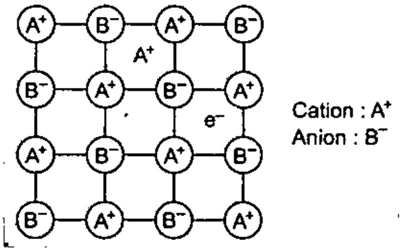
1. Which defect decreases density of the crystal?
(a) Frenkel defect (b) Schottky defect (c) Both (a) and (b) (d) None of these

2. Structure shown here represents:



(a) Schottky defect (b) Frenkel defect
(c) Metal excess defect (d) None of these

3. Structure shown here represents:



(a) Schottky defect (b) Frenkel defect (c) Both defects (d) None of these

PASSAGE 5

Doping means introduction of small amount of impurities like phosphorus, arsenic or boron into the pure crystal. In pure silicon, there are four valencies used in bonding with other four adjacent silicon atoms. When a silicon crystal is doped with a group-15 element (with five valence electrons) such as P, As, or Bi, the structure of the crystal lattice remains unchanged. Out of the five valence electrons of group-15 doped element, four electrons are used in normal covalent bonding with silicon while fifth electron is delocalised and thus conducts electricity.

Doping a silicon crystal with a group-13 element (with three valence electrons) such as B, Al, Ga or In products a semiconductor with three electrons in dopant. The place where fourth electron is missing is called an electron vacancy or hole. Such hole can move through the crystal like a positive charge giving rise of electricity.

1. No. of valence electrons in silicon are:
(a) 3 (b) 4 (c) 5 (d) 6

2. Silicon that has been doped with group-15 elements is called:
(a) *p*-type semiconductor (b) *n*-type semiconductor
(c) electron vacancy or hole (d) none of these

3. Silicon that has been doped with group-13 elements is called:
(a) *p*-type semiconductor (b) *n*-type semiconductor
(c) electron vacancy or hole (d) none of these

PASSAGE 6

Metallic Gold crystallise in fcc lattice and the length of cubic unit cell is 407 pm. (Given : Atomic mass of Gold $= 197, N_A = 6 \times 10^{23}$)

1. The density if it have 0.2% schottky defect is (in gm/cm^3) :
(a) 4.86 (b) 9.72 (c) 19.48 (d) 19.44

2. The distance between next neighbours is :
(a) 407 pm (b) $407\sqrt{2}$ (c) $\frac{407}{\sqrt{2}}$ (d) $\frac{407\sqrt{3}}{2}$

PASSAGE 7

In diamond structure, carbon atoms form FCC lattice and 50% tetrahedral voids occupied by carbon atoms. Every carbon atoms is surrounded tetrahedrally by four carbon atoms with bond length 154 pm. Germanium, silicon and grey tin also crystallise in same way as diamond. $(N_A = 6 \times 10^{23})$

1. The mass of diamond unit cell is :
(a) 96 amu (b) 96 gm (c) 144 amu (d) 144 gm

2. The side length of diamond unit cell is (in pm) :
(a) 154 (b) 1422.63 (c) 711.32 (d) 355.66

3. The density of diamond unit cell is (in gm/cm^3) :
(a) 28.48 (b) 0.0556 (c) 0.445 (d) 3.56

ONE OR MORE ANSWERS IS/ARE CORRECT

1. Select the correct statement(s):
(a) Co-ordination no. of an atom at a lattice point in simple cubic arrangement is 6
(b) Co-ordination no. of an atom at octahedral site is 8
(c) Co-ordination no. of an atom at a lattice point in hcp arrangement is 6
(d) Co-ordination no. of an atom at octahedral site is 6

2. Packing fraction of an identical solid sphere is 74% in:
(a) simple cubic structure (b) fcc structure
(c) hcp structure (d) bcc structure

3. In fcc structure octahedral sites are present at:
(a) edge centers (b) face centers (c) body centers (d) corners

4. If the radius of Na^+ is 95 pm and that of Cl^- ions is 181 pm then:
(a) Co-ordination no. of Na^+ is 6 (b) Co-ordination no. of Cl^- is 8
(c) Length of the unit cell is 552 pm (d) Length of the unit cell is 380 pm

5. Select the correct statement(s):
(a) The co-ordination number of each type of ion in a CsCl crystal is twelve
(b) A metal that crystallizes in a bcc structure has a co-ordination 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 in 552 pm (given that $r_{Na^+} = 85$ pm and $r_{Cl^-} = 181$ pm)

6. The hcp and ccp structure for a given element would be expected to have:
(a) the same co-ordination number (b) the same density
(c) the same packing fraction (d) all of the above

7. Select the correct statement(s) for the rock-salt structure (NaCl) :
(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 (r_c/r_a) is 0.225
(d) The radius ratio (r_c/r_a) is 0.732

8. Select the correct statement(s):
(a) The ionic crystal of AgBr may have Schottky defect
(b) The unit cell having crystal parameters, $a = b \neq c$, $\alpha = \beta = 90°$, $\gamma = 120°$ is hexagonal
(c) In ionic compounds having Frenkel defect the ratio r^+/r^- is high
(d) The co-ordination number of Na^+ ion in NaCl is 6

9. Which of the following represents the closest packed arrangement of uniform solid spheres:
(a) simple cubic unit cell (b) body centered cubic unit cell
(c) face centered cubic unit cell (d) hcp unit cell

10. Select the correct statement(s):
(a) A cubic system possesses a total of 23 elements of symmetry
(b) A cubic system contains centre of symmetry, planes of symmetry as well as axes of symmetry
(c) For triclinic system $a \neq b \neq c$ and $\alpha \neq \beta \neq \gamma \neq 90°$
(d) The total no. of Bravais space lattice belonging to all the seven crystals are 14

11. Select the correct statement(s):
(a) Co-ordination no. of Cs^+ and Cl^- are 8, 8 in CsCl crystal
(b) If radius ratio $(r_c/r_a) < 0.225$ then shape of compound must be linear
(c) If radius ratio (r_c/r_a) lies between 0.414 to 0.732 then shape of ionic compound may be square planer (Ex. $PtCl_4^{2-}$)
(d) If radius ratio is less than 0.155 then shape of compound is linear

12. Select the correct statement(s):
(a) CsCl changes to NaCl structure on heating
(b) NaCl changes to CsCl structure on applying pressure
(c) Co-ordination number decreases on applying pressure
(d) Co-ordination number increases on heating

13. Select the correct statement(s):
(a) A NaCl type *AB* crystal lattice can be interpreted to be made up of two individual fcc type unit lattice of A^+ and B^- fused together in such a manner that the corner of one unit lattice becomes the edge centre of the other
(b) In a fcc unit cell, the body center is an octahedral void
(c) In an scc lattice, there can be no octahedral void
(d) In an scc lattice, the body center is the octahedral void

14. In a *AB* unit cell (Rock salt type) assuming A^+ forming fcc:
(a) The nearest neighbour of A^+ is $6B^-$ ion (b) The nearest neighbour of B^- is $6A^+$ ion
(c) The second neighbour of A^+ is $12A^+$ (d) The packing fraction of *AB* crystal is $\frac{\sqrt{3}\pi}{8}$

15. Amorphous solids:
(a) do not have sharp melting points
(b) are isotropic
(c) have same physical properties in all directions
(d) are supercooled liquids

16. Which is/are correct statement about zinc blende structure ?
(a) The number of first neighbours of S^{2-} is 4
(b) The maximum distance between Zn^{2+} is $\frac{a\sqrt{3}}{2}$, where 'a' = edge length of unit cell
(c) If all tetrahedral voids occupied by Zn^{2+} then C.N. of S^{2-} is 8.
(d) If all tetrahedral voids occupied by Zn^{2+} then C.N. change from 4 : 4 to 8 : 8.

17. Compound X_2Y have antifluorite structure. Which is/are correct statement ?
(a) The minimum distance between X^+ is $\frac{a}{2}$, where 'a' = edge length of unit cell

(b) The co-ordination number is 8 : 4

(c) If X^+ removed from alternate tetrahedral void then CN is 4 : 4.

(d) If X^+ removed from alternate tetrahedral void then CN is 4 : 8

18. Which is/are correct statement ?

(a) Packing fraction in 2D-hcp is 0.785 (b) Packing fraction in *AAA* ..... is 0.52

(c) Packing fraction in *ABAB* ..... is 0.74 (d) Void fraction in *ABCABC* .... is 0.26

19. Which is/are correct statement ?

(a) In simple cubic close packed arrangement no octahedral void present at edge centre.

(b) In fcc unit cell octahedral void and tetrahedral void are vacant.

(c) Packing fraction : simple cubic unit cell < bcc unit cell < fcc unit cell

(d) Size of void: cubic void > octahedral void > tetrahedral void

20. Given : Radius of $A^{2+} = 100$ pm ; Radius of $C^+ = 240$ pm ; Radius of $B^{2-} = 300$ pm ; Radius of $D^- = 480$ pm Which is/are correct statement ?

(a) Coordination number of A^{2+} in comp *AB* is 4

(b) Coordination number of A^{2+} in comp *AB* is 6.

(c) Coordination number of C^+ in comp *CD* is 6

(d) Coordination number of C^+ in comp *CD* is 8.

MATCH THE COLUMN

Column-I and Column-II contains four entries each. Entries of Column-I are to be matched with some entries of Column-II. One or more than one entries of Column-I may have the matching with the same entries of Column-II.

1.

Column-I	**Column-II**
(A) Tetragonal and Hexagonal	(P) are two crystal systems
(B) Cubic and Rhombohedral	(Q) have cell parameters $a = b = c$ and $\alpha = \beta = 90° \neq \gamma$ are different
(C) Monoclinic and Triclinic	(R) $a \neq b \neq c$
(D) Cubic and Hexagonal	(S) $a = b = c$

2.

Column-I	**Column-II**
(A) If radius ratio $x = \left(\frac{r_c}{r_a}\right) < 0.155$	(P) Co-ordination no. is 8
(B) If $0.225 \le x < 0.414$	(Q) Co-ordination no. is 4
(C) If $0.414 \le x < 0.732$	(R) Co-ordination no. is 6
(D) If $0.732 \le x < 1$	(S) Co-ordination no. is 2

3.

Column-I (Shape of Compound)	**Column-II** (Co-ordination No.)
(A) Linear	(P) 6
(B) Triangular planar	(Q) 4
(C) Square planar	(R) 2
(D) Octahedral	(S) 3

4.

Column-I	**Column-II**
(A) Rock salt structure	(P) general formula is AB
(B) Zinc blende structure	(Q) general formula is AB_3
(C) Fluorite structure	(R) general formula is A_2B
(D) Anti fluorite structure	(S) general formula is AB_2

5.

Column-I	**Column-II**
(A) Co-ordination no. of Sa^{2+} and F^- in fluorite structure	(P) 8, 4
(B) C.No. of Zn^{2+} and S^{2-} in zinc blende structure	(Q) 8, 8
(C) C.No. of Cs^+ and Cl^- in CsCl (bcc type) structure	(R) 4, 8
(D) C.No. of Li^+ and O^{2-} in antifluorite structure	(S) 4, 4

6.

Column-I **[Bravais Lattice(s)]**	**Column-II** **(Crystal System)**
(A) Primitive, face centered, body centered, end centered	(P) Cubic
(B) Primitive, face centered, body centered	(Q) Orthorhombic
(C) Primitive, body centered	(R) Hexagonal
(D) Primitive only	(S) Tetragonal

7.

Column-I	Column-II
(A) Magnetic moment in a paramagnetic substance	(P) ↖ ↗ ↗ ↗ ↗ ↘
(B) Magnetic moment in a ferramagnetic	(Q) ↑ ↓ ↑ ↓ ↑ ↓
(C) Magnetic moment in a antiferromagnetic	(R) ↑ ↑ ↑ ↑ ↑ ↑
(D) Magnetic moment in a ferrimagnetic	(S) ↑ ↑ ↓ ↑ ↑ ↓

8.

Column-I (Structure)	Column-II (Edge length of unit cell)
(A) Rock salt (NaCl)	(P) $a = (r_{\text{Cation}} + r_{\text{Anion}})$
(B) CsCl	(Q) $a = \frac{4}{\sqrt{3}}(r_{\text{Cation}} + r_{\text{Anion}})$
(C) Zinc blende (ZnS)	(R) $a = \frac{2}{\sqrt{3}}(r_{\text{Cation}} + r_{\text{Anion}})$
(D) Anti fluorite (Na_2O)	(S) $a = 2(r_{\text{Cation}} + r_{\text{Anion}})$

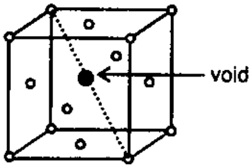
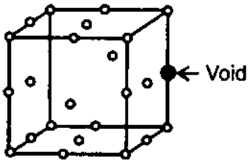
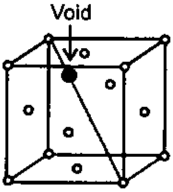
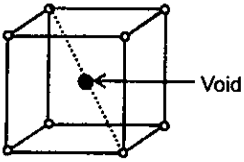
9.

Column-I (Ideal structure)	Column-II (Packing fraction)
(A) Rock salt	(P) 0.729
(B) Zinc blende	(Q) 0.756
(C) Fluorite	(R) 0.793
(D) CsCl	(S) 0.748

10.

Column-I (Structure)	Column-II (Voids occupied)
(A) Rock salt	(P) 100% tetrahedral voids occupied by cation
(B) Zinc blende	(Q) 100% tetrahedral voids occupied by anion
(C) Fluorite	(R) 100% octahedral voids occupied by cation
(D) Anti fluorite (Na_2O)	(S) 50% tetrahedral voids occupied by cation

4.

Column-I (Void representation)	**Column-II (Name of void)**
(A) 	(P) Tetrahedral void
(B) 	(Q) Octahedral void
(C) 	(R) Cubic void
(D) 	(S) Triangular void

ASSERTION-REASON TYPE QUESTIONS

Each question contains STATEMENT-1 (Assertion) and STATEMENT-2 (Reason).

Examine the statements carefully and mark the correct answer according to the instructions given below:

(A) If both the statements are TRUE and STATEMENT-2 is the correct explanation of STATEMENT-1

(B) If both the statements are TRUE but STATEMENT-2 is NOT the correct explanation of STATEMENT-1

(C) If STATEMENT-1 is TRUE and STATEMENT-2 is FALSE

(D) If STATEMENT-1 is FALSE and STATEMENT-2 is TRUE

1. **STATEMENT-1 :** In any ionic solid [*MX*] with Schottky defects, the number of positive and negative ions are the same.

   STATEMENT-2 : Equal number of cation and anion vacancies are present.

2. **STATEMENT 1 :** Amorphous solids are isotropic.

   STATEMENT 2 : Amorphous solids lack a regular three-dimensional arrangement of atoms.

3\. **STATEMENT-1 :** Diamond is a covalent solid.
STATEMENT-2 : The Co-ordination number of each carbon atom in diamond is 4.

4\. **STATEMENT-1 :** In NaCl structure, Na^+ ions occupy octahedral holes and Cl^- ions occupy ccp.
STATEMENT-2 : The distance of the nearest neighbours in NaCl structure is $a/2$ where a is the edge length of the cube.

5\. **STATEMENT-1 :** For fluorite structure, the F^- ions occupy tetrahedral void and Ca^{2+} ions in ccp
STATEMENT-2 : The radius ratio of fluorite structure is 0.414.

6\. **STATEMENT-1 :** In the body centered cubic type structure of CsCl the arrangement of Cs^+ is present in central octahedral void.
STATEMENT-2 : In CsCl, the Cs^+ ion at body centered position and Cl^- at corners.

7\. **STATEMENT-1 :** Electrical conductivity of semi-conductors increases with increasing temperature.
STATEMENT-2 : With increase in temperature, number of electrons from the valence bond can jump to the conduction band in semi-conductors.

8\. **STATEMENT-1 :** FeO is non-stoichiometric with $Fe_{0.95}O$.
STATEMENT-2 : Some Fe^{2+} ions are replaced by Fe^{3+} as $3Fe^{2+} = 2Fe^{3+}$ to maintain electrical neutrality.

9\. **STATEMENT-1 :** The number of tetrahedral voids is double the number of octahedral voids.
STATEMENT-2 : The size of the tetrahedral void is half of that of the octahedral void.

10\. **STATEMENT-1 :** Due to Frenkel defect there is no effect on density of a solid.
STATEMENT-2 : Ions shift from lattice sites to interstitial sites in Frenkel defect.

11\. **STATEMENT-1 :** Antiferromagnetic substances become paramagnetic on heating to high temperature.
STATEMENT-2 : Heating results in spins of electrons becoming random.

12\. **STATEMENT-1 :** Ionic crystals have the highest melting point.
STATEMENT-2 : Covalent bonds are stronger than ionic bonds.

SUBJECTIVE PROBLEMS

1. In seven possible crystal system how many crystal system have $\alpha = \beta$?
2. In seven possible crystal system how many crystal system have more than one Bravais lattice ?
3. How many effective no. of atoms present in BCC unit cell ?
4. In solid X atoms goes to corner of the cube and two alternate face centre. Calculate effective number of atom of X in unit cell ?
5. Find the distance (in pm) between the body centered atom and one corner atom in an element ($a = 2.32$ pm)

6. The structure of MgO is similar to NaCl. What is the co-ordination number of Mg ?

7. How many number of formula units in a unit cell of CaF_2 ?

8. What is the co-ordination number of sodium in Na_2O ?

9. Density of Li atom is $0.53 g/cm^3$. The edge length of Li is 3.5 Å. Find out the number of Li atoms in a unit cell. $(N_A = 6.0 \times 10^{23}\ mol^{-1},\ M = 6.94 g\ mol^{-1})$

10. What is the co-ordination number of Cl^- in CsCl structure ?

11. In cubic system how many atoms arrangement exist in nature ?

12. The ionic radii of A^+ and B^- are 1.7 Å and 1.8 Å respectively. Find the co-ordination number of A^+.

13. If edge fraction unoccupied in ideal anti-fluorite structure is x. Calculate the value of Z. Where $Z = \frac{x}{0.097}$

14. Ionic solid Na^+A^- crystallise in rock salt type structure. 2.592 gm of ionic solid salt NaA dissolved in water to make 2 litre solution. The pH of this solution is 8. If distance between cation and anion is 300 pm. Calculate density of ionic solid (in gm/cm^3).
(Given : $pK_w = 13, pK_a(HA) = 5, N_A = 6 \times 10^{23}$)

15. Calculate the value of $\frac{Z}{10}$. Where

Z = Co-ordination number of 2D-square close packing
+
Co-ordination number of 2D-hcp
+
Co-ordination number of 3D-square close packing
+
Co-ordination number of 3D, *ABCABC* ...... Packing
+
Co-ordination number of 3D, *ABAB* .... packing

ANSWERS

Level 1

1. (c)	2. (b)	3. (d)	4. (b)	5. (a)	6. (c)	7. (a)	8. (d)	9. (c)	10. (c)
11. (d)	12. (c)	13. (d)	14. (a)	15. (b)	16. (a)	17. (b)	18. (c)	19. (a)	20. (b)
21. (d)	22. (c)	23. (b)	24. (c)	25. (d)	26. (c)	27. (c)	28. (c)	29. (c)	30. (b)
31. (c)	32. (a)	33. (d)	34. (c)	35. (b)	36. (b)	37. (c)	38. (a)	39. (a)	40. (d)
41. (d)	42. (d)	43. (b)	44. (d)	45. (c)	46. (d)	47. (c)	48. (b)	49. (a)	50. (b)
51. (b)	52. (b)	53. (c)	54. (a)	55. (c)	56. (b)	57. (a)	58. (d)	59. (c)	60. (b)
61. (d)	62. (c)	63. (a)	64. (a)	65. (b)	66. (a)	67. (b)	68. (c)	69. (b)	70. (b)
71. (b)	72. (c)	73. (b)	74. (d)	75. (a)	76. (d)	77. (c)	78. (c)	79. (a)	80. (a)
81. (c)	82. (c)	83. (b)	84. (c)	85. (a)	86. (c)	87. (c)	88. (d)	89. (d)	90. (b)
91. (b)	92. (c)	93. (c)	94. (a)	95. (b)	96. (d)	97. (c)	98. (d)	99. (a)	100. (b)
101. (c)	102. (d)	103. (d)	104. (c)	105. (a)	106. (d)	107. (b)	108. (d)	109. (d)	110. (c)
111. (c)	112. (c)	113. (b)	114. (c)	115. (b)	116. (c)	117. (a)	118. (c)	119. (d)	120. (b)
121. (b)	122. (a)	123. (b)	124. (c)	125. (d)					

Level 2

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

Level 3

Passage–1: 1. (c) 2. (a)

Passage–2: 1. (d) 2. (a) 3. (c)

Passage–3: 1. (b) 2. (b) 3. (a) 4. (a)

Passage–4: 1. (b) 2. (b) 3. (d)

Passage–5: 1. (b) 2. (b) 3. (a)

Passage–6: 1. (d) 2. (a)

Passage–7: 1. (a) 2. (d) 3. (d)

One or More Answers is/are correct

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

Match the Column

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

Assertion-Reason Type Questions

1. (A) 2. (A) 3. (B) 4. (B) 5. (C) 6. (D) 7. (A) 8. (A) 9. (C) 10. (A)
11. (A) 12. (C)

Subjective Problems

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

Hints and Solutions

Level 1

44. (d) Effective no. of atoms in a unit cell = 4

No. of atoms = $\frac{8}{80} \times N_A$

∴ No. of unit cell= $\frac{N_A}{10} \times \frac{1}{4}$

45. (c) Use $a^3 = \frac{Z}{\rho}\left(\frac{M}{N_A}\right)$

$a = 314$ pm . $r = \frac{\sqrt{3}a}{4} \Rightarrow 135.96$ pm

51. (b) The ccp structure generates fcc unit cell

So, $\sqrt{2}a = 4r$

$a = 608.2$ pm

52. (b) $\rho = \frac{Z.M}{N_A a^3} \Rightarrow N_A = \frac{4 \times 59}{(9.0)(3.5 \times 10^{-8})^3}$

$= 6.11 \times 10^{23}$

59. (c) Spheres of any two adjacent layer should not be repeated on each other.

81. (c) Effective no. of atoms of $A = 1 - \frac{1}{8} \Rightarrow \frac{7}{8}$

Effective no. of atoms of $B = 6 \times \frac{1}{2} \Rightarrow 3$

$A_{7/8}B_3$ or general formula is A_7B_{24}

83. (b) Effective no. of O^{2-} in a unit cell

$= 8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 4$

Effective no. of A^{2+} in a unit cell = $8 \times \frac{1}{8} = 1$

Effective no. of B^{3+} in a unit cell = $4 \times \frac{1}{2} = 2$

∴ general formula is AB_2O_4

84. (c) Effective no. of A in a unit cell = 6

Effective no. of C in a unit cell = $6 \times \frac{2}{3} = 4$

So, general formula is C_2A_3

87. (c) Effective no. of Cu in a unit cell

$= 8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 4$

Effective no. of Ag in a unit cell = $12 \times \frac{1}{4} = 3$

Effective no. of Au in a unit cell = 1

So, general formula of compound is Cu_4Ag_3Au

100. (b) $a = 2(r^+ + r^-) \Rightarrow 400 = 2(80 + r_a)$

∴ $r_a = 120$

102. (d) In ideal fluorite type structure; cation is present in tetrahedral void

So, $\frac{r_c}{r_a} = 0.225$

104. (c) $\sqrt{3}a = 2(r^+ + r^-)$

$\Rightarrow a = \frac{2 \times (1.69 + 1.81)}{1.732}$

$\Rightarrow = 4.04$ Å

105. (a) $\sqrt{3}a = 2(r^+ + r^-)$

∴ $r^+ + r^- \Rightarrow 3.72$ pm

119. (d) Density of crystal always increases due to substitutional impurity defect.

120. (b) $\sqrt{3}a = 4(2r)$

121. (b) ∵ $2Na^+$ replaced by one Sr^{2+};

1 mole of NaCl contain 10^{-7} mole of Sr^{2+}

∴ no. of cationic vacancies $= 10^{-7} \times N_A$

122. (a) Three Fe^{2+} replaced by two Fe^{3+}

total loss of iron = 0.07 mole

So, mole of Fe^{3+} present in $Fe_{0.93}O$

$= 2 \times 0.07$

∴ % of Fe^{3+} in total iron content

$= 2 \times \frac{0.07}{0.93} = 15.05$

123. (b) Two Cu^+ replaced by one Cu^{2+}

Total loss of Cu = 0.2 mole

So, mole of Cu^{2+} present in $Cu_{1.8}S$ = 0.2

∴ % of Cu^{2+} in total copper content

$= \frac{0.2}{1.8} \times 100$

$= 11.11$

Level 2

1. (b) $\rho_1 = \dfrac{2\times 56}{\left(\dfrac{4r}{\sqrt{3}}\right)^3}$; $\rho_2 = \dfrac{4\times 56}{(2\sqrt{2}r)^3}$

$$\frac{\rho_1}{\rho_2} \Rightarrow 0.918$$

2. (c) $2.32 = \dfrac{2\times M}{6\times 10^{23}\,(1.22)^3\times 10^{-21}}$

$$\Rightarrow \quad M = 1264 \quad \Rightarrow \quad x \approx 47$$

3. (c) Edge not covered by atom $= a - 2r$

also in bcc, $4r = \sqrt{3}a$

Therefore, edge not covered

$$= a - \frac{\sqrt{3}}{2}a = a\left(\frac{2-\sqrt{3}}{2}\right)$$

$\Rightarrow$ Fraction of edge not covered by atoms

$$= \frac{2-\sqrt{3}}{2} = 0.134$$

4. (c) In a simple cubic crystal, $a = 2r$

Let the radius of the interstitial atom in simple cubic structure be x, then

$$2(r+x) = \sqrt{3}a = \sqrt{3}\times 2r$$

So, $\quad x = \sqrt{3}r - r \Rightarrow 0.732r$

$$\text{Packing fraction} = \frac{\frac{4}{3}\pi r^3 + \frac{4}{3}\pi(0.732r)^3}{(2r)^3}$$

$$= \frac{\frac{4}{3}\pi r^3\,[1+(0.732)^3]}{8r^3}$$

$$= \frac{\pi}{6}[1+(0.732)^3] = 0.73$$

5. (d) Given $a - 2r = 60.3$ and for bcc, $4r = \sqrt{3}a$

$$\Rightarrow \quad a - \frac{\sqrt{3}}{2}a = 60.3 \quad \Rightarrow \quad a = 450\text{ pm}$$

$$\text{Density }(\rho) = \frac{2\times 48}{6.023\times 10^{23}\times(4.5)^3\times 10^{-24}}$$

$$= 1.75\text{ g/cc}$$

6. (c) $\qquad a - 2r = 53.6\text{ pm} \qquad \ldots\text{(i)}$

also $\qquad 4r = \sqrt{3}a$

$$\Rightarrow \quad a - \frac{\sqrt{3}}{2}a = 53.6$$

$$\Rightarrow \quad a = \frac{53.6\times 2}{2-\sqrt{3}} = 400\text{ pm}$$

$$\text{Density }(\rho) = \frac{2\times 23}{6.023\times 10^{23}\times 4^3\times 10^{-24}}$$

$$= 1.19\text{ g/cc}$$

7. (b) Vol. of all atoms in 1.68 g of Ar

$$= \frac{1.68}{40}\times 6\times 10^{23}\times\frac{4}{3}\times\frac{22}{7}\times(1.50^3\times 10^{-8})$$

$$= 0.3564$$

Vol. of solid Ar = 1 cm^3

% of empty space $= (1 - 0.3564)\times 100$

$= 64.36$

8. (d) Effective no. of atoms of B present in a unit cell = 2

Total volume of B unoccupied by A in a unit cell

$$= 2\times\frac{4}{3}(R^3 - r^3)\times\pi$$

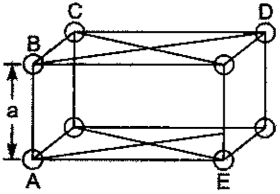
$$= \frac{7\pi R^3}{3} \qquad \left(\because\ r = \frac{R}{2}\right)$$

Volume of unit cell $= a^3$

$$\Rightarrow \quad \left(\frac{4R}{\sqrt{3}}\right)^3 = \frac{64}{3\sqrt{3}}R^3 \qquad (\because\ \sqrt{3}a = 4R)$$

$$\text{Desired ratio} \Rightarrow \frac{\dfrac{7\pi R^3}{3}}{\dfrac{64}{3\sqrt{3}}R^3} = \frac{7\pi\sqrt{3}}{64}$$

9. (a)

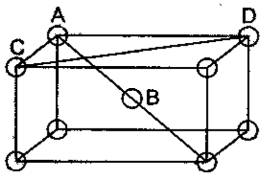


$AB = a$ (nearest)

$BD = \sqrt{2}a$ (next-nearest)

$CE = \sqrt{3}a$ (next-next-nearest)

10. (c)



$AB = \dfrac{\sqrt{3}a}{2}$ (nearest)

$AC = a$ (next-nearest)

$CD = \sqrt{2}a$ (next-next-nearest)

11. (a) Atoms of three layers (*ABC*) are present in fcc unit cell generated by cubic closest packing.

12. (b) Let volume of fcc unit cell = *V*

$$\rho_A = \frac{4 \times M_A}{N_A . V}$$

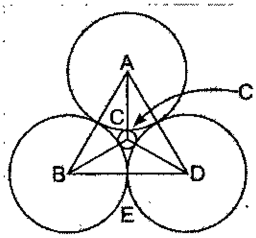
$$\rho_B = \frac{8 \times M_B}{N_A . V}$$

$$\frac{\rho_A}{\rho_B} = \frac{M_A}{2M_B} = \frac{30}{2 \times 50} = 0.3$$

$$\rho_B = \frac{\rho_A}{0.3} = 3.33 \text{ g/cc}$$

Total density $\rho_A + \rho_B = 4.33$ g/cc

13. (c)



$$\frac{BE}{BC} = \cos 30° = \frac{\sqrt{3}}{2}$$

Distance between the centres of two *B* atoms

$$= 2 \times BE = \sqrt{3} \text{ Å}$$

14. (d) 4 formula unit of *AB* is present in a unit cell

$$\therefore \text{ no. of unit cell } = \frac{4}{40} \times \frac{N_A}{4}$$

$$\Rightarrow \quad 0.025 N_A$$

15. (c) Use $\rho = \frac{Z.M}{N_A . a^3}$

$$Z = 4; \quad M = 40 + 2 \times 19$$

16. (a) $a = 2(r^+ + r^-)$

$$= 2 \times 297 \text{ pm}$$

Volume of unit cell = a^3

$$= 209.6 \times 10^{-24} \text{ cm}^3$$

17. (b) $8.27 = \frac{4 \times 128}{6.023 \times 10^{23} \, a^3}$

$$\Rightarrow \quad a = 46.8 \times 10^{-9} \text{ cm} = 4.68 \text{ Å}$$

$$= 2[r_{O^{2-}} + r_{Cd^{2+}}]$$

$$\Rightarrow \quad r_{Cd^{2+}} = 1.1 \text{ Å}$$

18. (a) $\frac{r_{Na^+} + r_{Cl^-}}{r_{Cl^-}} = 1.5$

and $\frac{r_{K^+}}{r_{Cl^-}} = \frac{5}{7}$ or $\frac{r_{K^+} + r_{Cl^-}}{r_{Cl^-}} = \frac{12}{7}$

$$\frac{a_1}{a_2} = \frac{2(r_{K^+} + r_{Cl^-})}{2(r_{Na^+} + _{Cl^-})}$$

$$= \frac{12}{7} \times \frac{1}{1.5} = 1.143$$

19. (a) Mass of unit cell = $d \times V$

$$= (5 \times 10^{-8})^3 \times 3.84 \times 6 \times 10^{23}$$

$$= 288 \text{ a.m.u.}$$

Mass of formula unit of FeO = 56 + 16 = 72 a.m.u.

$$\therefore \text{ no. of formula unit } = \frac{288}{72} = 4$$

20. (b) Density crystal decreases due to Schottky defects effective no. of atoms per unit cell in given lattice

$$= 4\left(1 - \frac{0.25}{100}\right) = 3.99$$

$$\rho = \frac{50 \times 3.99}{6 \times 10^{23} \, (0.50 \times 10^{-7})^3}$$

$$\Rightarrow \quad = \frac{50 \times 3.99}{6 \times 125 \times 0.1}$$

$$\rho = 2.66 \text{ g/cm}^3$$

21. (a) Theoretical density = $\frac{Z.M}{N_A . a^3}$

$$= \frac{4 \times 24 \times 10^{-3}}{6 \times 10^{23} \times (4 \times 10^{-10})^3}$$

$$= 2.5 \times 10^3 \text{ kg/m}^3$$

$$\% \text{ occupancy} = \frac{\text{Observed density}}{\text{Ideal density}} \times 100$$

$$= \frac{2.4 \times 10^3}{2.5 \times 10^3} \times 100 = 96\%$$

23. (d) Octahedral void present at the centre of cube and tetrahedral void is present at (1/4)th of the distance along each body diagonal.

$\therefore \frac{\sqrt{3}a}{2} = 2 \times$ distance between octahedral and tetrahedral void.

24. (d) Vol. of unit cell = $a^2 \sin 60° \times b$

$$= 173.2 \times 10^{-24} \text{ cm}^3$$

$$a = 5 \text{ Å}$$

Mass of unit cell

$$= 173.2 \times 10^{-24} \times 5 \times 6 \times 10^{23}$$

$$= 519.6 \text{ g}$$

No. of molecules present in given unit cell

$$= \frac{519.6}{259.8} = 2$$

25. (b) In hcp arrangement total height

$$h = 4 \times \sqrt{\frac{2}{3}}\, r$$

as per given

$$\frac{h}{2} = 2\sqrt{\frac{2}{3}}\, r = 3.35 \text{ Å} = 3.35 \times 10^{-8} \text{ cm.}$$

Volume of unit cell $= 24\sqrt{2}r^3$

$$= 24\sqrt{2}\left(\sqrt{\frac{3}{2}} \times \frac{1}{2} \times 3.35 \times 10^{-8}\right)^3$$

$$= 2.93 \times 10^{-22} \text{ cm}^3$$

Effective no. of atoms in hexagonal unit cell $= 6$

$$\therefore \text{ density} = \frac{6 \times 12}{6.023 \times 10^{23} \times 2.93 \times 10^{-22}}$$

$$= 0.41 \text{ g/cc}$$

26. (a) No. of $Na^+ = 4 - 1 = 3$

No. of $Cl^- = 4 - \left(2 \times \frac{1}{2}\right) = 3$

27. (b) Along one body diagonal 2X atoms from 2 corners, one Y particle (at the centre of cube) will be removed.

So, effective no. of X particles in a unit cell

$$= 4 - \left(2 \times \frac{1}{8}\right) = \frac{15}{4}$$

and effective no. of Y particles in a unit cell

$$= 4 - 1 = 3$$

$$X : Y \quad \frac{15}{4} : 3$$

or $\quad 5 : 4$

28. (b) Effective no. of $Na^+ = 4 - \left(1 + 2 \times \frac{1}{4}\right) = \frac{5}{2}$

For $Cl^- = 4\sqrt{2}a = 4r^-$

$$\text{P. F.} = \frac{\text{Vol. of effective no. of cations and anions}}{\text{Vol. of unit cell}}$$

29. (d) No. of X particles per unit cell $= 4$

No. of Y particles $= 4$

No. of Z particles $= 8$

Along one body diagonal 2X atoms from 2 corners, one Y particle and 2Z particles will be removed.

So, effective no. of X particles in a unit cell

$$= 4 - \frac{1}{8} \times 2 = \frac{15}{4}$$

Effective no. of Y particles in a unit cell

$$= 4 - 1 = 3$$

Effective no. of Z particles in a unit cell

$$= 8 - 2 = 6$$

$$X : Y : Z$$

$$\frac{15}{4} : 3 : 6$$

$$5 : 4 : 8$$

30. (a) Effective no. of A particles are removed

$$= 4 \times \frac{1}{8} + 2 \times \frac{1}{2} = \frac{3}{2}$$

Effective no. of A particles present in a unit cell

$$= 4 - \frac{3}{2} = \frac{5}{2}$$

Effective no. of B particles are removed

$$= 2 \times \frac{1}{4} + 1 = \frac{3}{2}$$

Effective no. of B particles present in a unit cell

$$= 4 - \frac{3}{2} = \frac{5}{2}$$

$$A : B$$

$$\frac{5}{2} : \frac{5}{2} \quad \text{or} \quad 1 : 1$$

Level 3

Passage-1

1. (c) $\text{P. F.} = \dfrac{2 \times \frac{4}{3}\pi r^3}{\left(\frac{4r}{\sqrt{3}}\right)^3} \simeq 0.68$

% of empty space $= 100 - 0.68 \times 100 = 32$

2. (a) $\text{P. F.} = \dfrac{4 \times \frac{4}{3}\pi r^3}{\left(\frac{4r}{\sqrt{2}}\right)^3} = 0.7406$

Passage-2

1. (a) $10.6 = \dfrac{4 \times 108}{a^3 \times 6.023 \times 10^{23}}$

$\therefore\ a = 4.07$ nm

2. (a) Mass of 12×10^{23} atoms $= 100$ gm

Mass of 6.022×10^{23} atom

$$= \frac{100}{12 \times 10^{23}} \times 6.023 \times 10^{23}$$

$$= 50.18$$

$$\therefore \quad \rho = \frac{4 \times 50.18 \times 10}{6.023 \times 10^{23} \times (200 \times 10^{-10})^3}$$

$$= 41.66\ \text{g/cm}^3$$

3. (c) By Hit and Trial : For fcc $Z = 4$ (4 pairs of KBr)

$$M = 39 + 80 = 119$$

Passage-3

3. (a) 1 to 3

c.c.p. generated f.c.c. and octahedral voids = effective number of atoms in a unit cell

4. (a) O^{2-} is replaced by $X^{8/3-}$ so formula of spinel is $MgAl_2X_3$ and deficiency by one anion.

Subjective Problems

15. $Z = 4 + 6 + 6 + 12 + 12 = 40$

$$\frac{Z}{10} = \frac{40}{10} = 4$$