

# **S O L I D   S T A T E**

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## **Syllabus**

**Solid state:** Classification of solids, crystalline state, seven crystal systems (cell parameters  $a, b, c, \alpha, \beta, \gamma$ ), close packed structure of solids (cubic), packing in fcc, bcc and hcp lattices; Nearest neighbours, ionic radii, simple ionic compounds, point defects.

Name : \_\_\_\_\_ Contact No. \_\_\_\_\_

# SOLID STATE

## Difference between Crystalline and Amorphous Solids :

### Crystalline solids

They have definite and regular geometry due to definite and orderly arrangement of atoms, ions or molecules in three-dimensional space.

### Amorphous solids

They do not have any pattern of arrangement of atoms, ions or molecules and, thus do not have any definite geometrical shape.

## TYPES OF CRYSTALLINE SOLIDS :

|                                    | Ionic                                                 | Metallic                                                  | Covalent                                          | molecular                                                   |
|------------------------------------|-------------------------------------------------------|-----------------------------------------------------------|---------------------------------------------------|-------------------------------------------------------------|
| Particles occupying lattice points | Anions, cations                                       | Metal ions in electron cloud                              | Atoms                                             | Molecules (or atoms)                                        |
| Binding force                      | Electrostatic attraction                              | Metallic bonds                                            | Covalent bonds                                    | Van der waals dipole-dipole                                 |
| Properties                         | Hard, Brittle, poor thermal and electrical conductors | Soft to very hard, good thermal and electrical conductors | Very hard, poor thermal and electrical conductors | Soft, poor thermal and electrical conductors                |
| Example                            | NaCl, CaBr <sub>2</sub> , KNO <sub>3</sub> , etc      | Li, K, Ca, Cu, Na, etc.                                   | C(diamond) SiO <sub>2</sub> (quartz), etc         | H <sub>2</sub> O, H <sub>2</sub> , CO <sub>2</sub> , Ar etc |

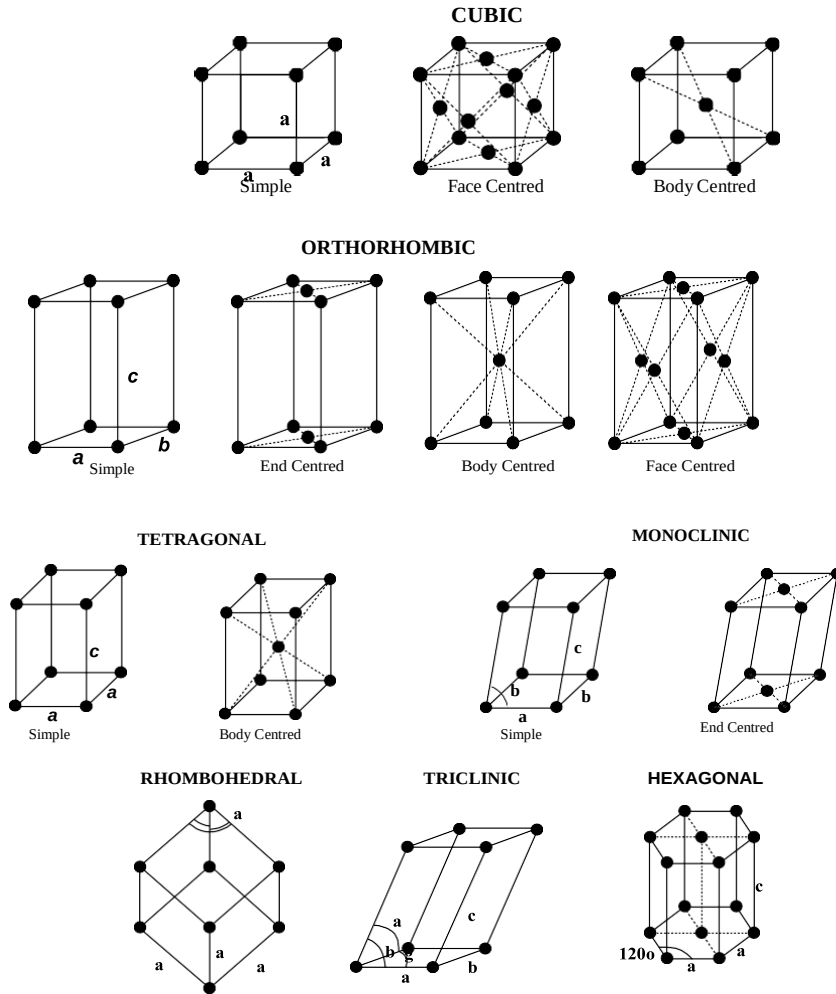
## Space lattice or crystal lattice :

It may be defined as a regular three dimensional arrangement of identical points in space.

## Seven Crystal Systems :

| Crystal System                                                     | Bravais Lattices                                          | Parameters of Unit Cell |                                                         | Example                                                                                 |
|--------------------------------------------------------------------|-----------------------------------------------------------|-------------------------|---------------------------------------------------------|-----------------------------------------------------------------------------------------|
|                                                                    |                                                           | Intercepts              | Interfacial angle                                       |                                                                                         |
| 1. Cubic                                                           | Primitive, Face Centered, Body Centered = 3               | $a = b = c$             | $\alpha = \beta = \gamma = 90^\circ$                    | Pb, Hg, Ag, Au<br>Diamond,<br>NaCl, ZnS                                                 |
| 2. Tetragonal                                                      | Primitive, Body Centered = 2                              | $a = b \neq c$          | $\alpha = \beta = \gamma = 90^\circ$                    | TiO <sub>2</sub> , SnO <sub>2</sub>                                                     |
| 3. Orthorhombic                                                    | Primitive, Face Centered, Body Centered, End Centered = 4 | $a \neq b \neq c$       | $\alpha = \beta = \gamma = 90^\circ$                    | KNO <sub>3</sub> , K <sub>2</sub> SO <sub>4</sub>                                       |
| 4. Hexagonal                                                       | Primitive = 1                                             | $a = b \neq c$          | $\alpha = \beta = 90^\circ$ ,<br>$\gamma = 120^\circ$   | Mg, SiO <sub>2</sub> , Zn, Cd                                                           |
| 5. Rhombohedral                                                    | Primitive = 1                                             | $a = b = c$             | $\alpha = \beta = \gamma \neq 90^\circ$                 | As, Sb, Bi, CaCO <sub>3</sub>                                                           |
| 6. Monoclinic                                                      | Primitive, End Centered = 2                               | $a \neq b \neq c$       | $\alpha = \gamma = 90^\circ$ ,<br>$\beta \neq 90^\circ$ | CaSO <sub>4</sub> ·2H <sub>2</sub> O                                                    |
| 7. Triclinic                                                       | Primitive = 1                                             | $a \neq b \neq c$       | $\alpha \neq \beta \neq \gamma \neq 90^\circ$           | K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> ,<br>CaSO <sub>4</sub> ·5H <sub>2</sub> O |
| Total = 14 (Total 14 type of lattices are called Bravais lattices) |                                                           |                         |                                                         |                                                                                         |

## Seven Crystal Systems and Fourteen Bravais Lattice :



| Type of Lattice point | Contribution to one unit cell |
|-----------------------|-------------------------------|
| Corner                | 1/8                           |
| Edge                  | 1/4                           |
| Face-center           | 1/2                           |
| Body Center           | 1                             |

### Calculation of number of particles in a unit cell

| Type of unit cell | Lattice points at corners | Lattice points at face-centered | Lattice points at body centered | Z = no. of lattice points per unit cell           |
|-------------------|---------------------------|---------------------------------|---------------------------------|---------------------------------------------------|
| SCC               | 8                         | 0                               | 0                               | $8 \times \frac{1}{8} = 1$                        |
| BCC               | 8                         | 0                               | 1                               | $8 \times \frac{1}{8} + 1 \times 1 = 2$           |
| FCC               | 8                         | 6                               | 0                               | $8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 4$ |

## Relation between edge length of unit cell and radius of atoms :

**Simple cubic or Primitive** : edge length of unit cell  $a = 2 r$

**Body centre cubic** : atomic radius,  $r = \frac{\sqrt{3} a}{4}$

**Face centre cubic/cubic close packed** : atomic radius  $r = \frac{\sqrt{2} a}{4}$

## Fraction of volume occupied by atoms in a cube :

**Packing Fraction = Volume of atoms in the cube/Total volume of cube)**

|     | Item                                                                 | Primitive                      | BCC                                   | FCC                                  |
|-----|----------------------------------------------------------------------|--------------------------------|---------------------------------------|--------------------------------------|
| 1.  | Atoms occupy :                                                       | 8 corners                      | 8 corners, 1 centre                   | 8 corners, 6 face centres            |
| 2.  | Each atom contributes                                                |                                |                                       |                                      |
|     | (a) corner atom :                                                    | $\frac{1}{8}$ th $\times 8$    | $\frac{1}{8}$ th $\times 8$           | $\frac{1}{8}$ th $\times 8$          |
|     | (b) Face centre atom :                                               | nil                            | nil                                   | $\frac{1}{6} \times 6$               |
|     | (c) Body centre atom :                                               | nil                            | one $\times$ one                      | nil                                  |
| 3.  | $\therefore$ No. of atoms in the cube (Z):                           | one                            | two                                   | four                                 |
| 4.  | Radius of the atom :                                                 | $r$                            | $r$                                   | $r$                                  |
| 5.  | Total volume of atoms :                                              | $1 \times \frac{4}{3} \pi r^3$ | $2 \times \frac{4}{3} \pi r^3$        | $4 \times \frac{4}{3} \pi r^3$       |
| 6.  | Edge of the cube :                                                   | $a$                            | $a$                                   | $a$                                  |
| 7.  | Edge of the cube in terms of $r$ :                                   | $a = 2 r$                      | $a = \frac{4}{\sqrt{3}} r$            | $a = \frac{4r}{\sqrt{2}}$            |
| 8.  | Total volume of the cube, $a^3$ :                                    | $(2r)^3$                       | $\left(\frac{4}{\sqrt{3}} r\right)^3$ | $\left(\frac{4r}{\sqrt{2}}\right)^3$ |
| 9.  | Fraction of volume occupied :                                        | $\frac{4}{3} \pi r^3$          | $\frac{8}{3} \pi r^3$                 | $\frac{16}{3} \pi r^3$               |
|     | $= \frac{\text{Total volume of atoms}}{\text{Total volume of cube}}$ | $\frac{4}{3} \pi r^3$          | $\frac{64}{3\sqrt{3}} r^3$            | $\frac{64}{2\sqrt{2}} r^3$           |
| 10. | (or) packing fraction :                                              | $\frac{\pi}{6}$                | $\frac{\sqrt{3}}{8} \pi$              | $\frac{\sqrt{2} \pi}{6}$             |
| 11. | (or) volume occupied by atoms :                                      | 0.52                           | 0.6802                                | 0.7405                               |
| 12. | % volume occupied by atoms :                                         | 52%                            | 68.02 %                               | 74.05%                               |
| 13. | Fraction of void volume :                                            | 0.48                           | 0.3198                                | 0.2595                               |
| 14. | % of void volume in cube :                                           | 48%                            | 31.98%                                | 25.95%                               |
| 15. | % of empty space in cube :                                           | 48%                            | 31.98%                                | 25.95%                               |

## Density of unit cell :

$$\text{Density of unit cell (and hence density of a crystal)} \rho = \frac{Z \times M}{a^3 \times N_0 \times 10^{-30}}$$

where a is edge of unit cell in pm

$N_0$  = Avogadro number ( $6.02 \times 10^{23}$ )

M = Atomic mass of element or formula mass of the compound

Z = No. of atoms present per unit cell or formula units. e.g.

for fcc, Z = 4, for bcc, Z = 2, for simple cubic, Z = 1

## Close packing in crystals :

### Close packing in three dimensions

When the third layer is placed over the second layer. This arrangement is called ABAB,... pattern or hexagonal (HCP) close packing.

(a) For HCP geometry Coordination number = 12

(b) For HCP geometry no. of atoms per unit cell

$$= 12 (\text{corners}) \times \frac{1}{6} + 2 (\text{face centres}) \times \frac{1}{2} + 3 (\text{inside the body}) \times 1 = 6$$

(c) For HCP geometry packing efficiency = 74 %

The ABC ABC ..... packing has cubic symmetry and is known as cubic close packing (ccp). The cubic close packing close packing has face centered cubic (fcc) unit cell.

## Types of Voids

|                     |                                                     |                       |                                                     |
|---------------------|-----------------------------------------------------|-----------------------|-----------------------------------------------------|
| <b>Triangular</b> : | $\frac{r_{\text{void}}}{r_{\text{sphere}}} = 0.155$ | <b>Tetrahedral</b> :  | $\frac{r_{\text{void}}}{r_{\text{sphere}}} = 0.225$ |
| <b>Octahedral</b> : | $\frac{r_{\text{void}}}{r_{\text{sphere}}} = 0.414$ | <b>cubical void</b> : | $\frac{r_{\text{void}}}{r_{\text{sphere}}} = 0.732$ |

Common coordination numbers are 3, 4, 6 and 8.

| Limiting $\frac{r_a}{r_c}$ radius ratio | Co-ord. No. | Shape           |                               |
|-----------------------------------------|-------------|-----------------|-------------------------------|
| <b>Example</b>                          |             |                 |                               |
| < 0.155                                 | 2           | Linear          | BeF <sub>2</sub>              |
| 0.155 – 0.225                           | 3           | Trigonal planar | B <sub>2</sub> O <sub>3</sub> |
| 0.225 – 0.414                           | 4           | Tetrahedral     | ZnS                           |
| 0.414-0.732                             | 4           | square planar   | PtCl <sub>4-2</sub>           |
| 0.414-0.732                             | 6           | octahedral      | NaCl                          |
| 0.732 - 0.999                           | 8           | B.C.C.          | CsCl                          |

## Structure of ionic compounds :

### Structures of Type AB :

1. Rock salt (NaCl) type
2. Cesium chloride (CsCl) type
3. Zinc blende (ZnS) type

### Rock salt structure (NaCl) :

(a)  $\text{Cl}^-$  is forming a FCC unit cell in which  $\text{Na}^+$  is in the octahedral voids. The co-ordination number of  $\text{Na}^+$  is 6 and that of  $\text{Cl}^-$  would also be 6.

(b) Ratio of ionic radii =  $\left( \frac{r_{\text{Na}^+}}{r_{\text{Cl}^-}} = 0.525 \right)$

(c) No. of sodium ions =  $12 \text{ (At edge centre)} \times \frac{1}{4} + 1 \text{ (At bodycentre)} \times 1 = 4$

No. of chloride ions =  $8 \text{ (At corners)} \times \frac{1}{8} + 6 \text{ (At face centres)} \times \frac{1}{2} = 4$  (Thus formula is  $\text{Na}_4\text{Cl}_4$  i.e. NaCl)

### Caesium chloride structure (CsCl) :

(a) CsCl has body-centered cubic (bcc) arrangement. This structure has 8 : 8 co-ordination, i.e., each  $\text{Cs}^+$  ion is touching eight  $\text{Cl}^-$  ions and each  $\text{Cl}^-$  ions in touching eight  $\text{Cs}^+$  ions. (bcc)

(b) No. of  $\text{Cl}^-$  ions =  $8 \text{ (At corners)} \times \frac{1}{8} = 1$

No. of  $\text{Cs}^+$  ions =  $1 \text{ (At the body centre)} \times 1 = 1$

No. of CsCl unit per unit cell = 1

### Zinc blende structure or sphalerite structure (ZnS) :

(a) Sulphite ions are face centered and zinc is present in alternate tetrahedral voids.

(b)  $\frac{r_{\text{Zn}^{2+}}}{r_{\text{S}^{2-}}} = 0.40 \quad \therefore \text{No. of ZnS units per unit cell} = 4$

**Fluorite structure ( $\text{CaF}_2$ ) :** The cations are arranged in cubic close packing (ccp) while the anion occupy all the tetrahedral voids. Calcium fluoride has 8 : 4 co-ordination. (ccp)

$\therefore$  No. of  $\text{CaF}_2$  units per unit cell = 4

**Antifluorite structure :** In antifluorite structure e.g., ( $\text{Na}_2\text{O}$ )

(a) The anions are arranged in cubic close packing (ccp) while the cations occupy all the tetrahedral voids.

(b)  $\text{Na}_2\text{O}$  has 4 : 8 co-ordination

**WURTZITE structure :** Sulphide ions have hcp arrangement and zinc ions occupy tetrahedral voids.

**Spinal structure :** General formula of compound is  $\text{AB}_2\text{O}_4$  e.g.,  $\text{MgAl}_2\text{O}_4$ ,  $\text{ZnFe}_2\text{O}_4$

Oxide ions are arranged in ccp arrangement. Divalent cations are in tetrahedral sites and trivalent ions are in octahedral sites.

### Imperfections or defects in solids :

#### Stoichiometric point defects :

(a) **Schottky Defects :** This type of defect is created when one positive ion and one negative ion are missing from their respective positions leaving behind a pair of holes. Schottky defects are more common in ionic compounds with high co-ordination number.

(b) **Frenkel Defect –** This type of defect is created when an ion leaves its correct lattice site and occupies an interstitial site. Frenkel defects are common in ionic compounds which have low co-ordination number and in which there is large difference in size between positive and negative ions.

#### Non Stoichiometric defects :

**Metal excess Defects due to Anion Vacancies.** A compound may have excess metal ion if a negative ion is absent from its lattice site, leaving a 'hole', which is occupied by electron to maintain electrical neutrality.

**Metal Deficiency due to cations vacancies.** The non-stoichiometric compounds may have metal deficiency due to the absence of a metal ion from its lattice site. The charge is balanced by an adjacent ion having higher positive charge.

# EXERCISE # 1

## PART - I : OBJECTIVE QUESTIONS

\* Marked Questions are having more than one correct option.

### Section (A) : Interparticle Forces & Classification of Solids

**A-1** For each of the following substances,  $\text{Al}_2\text{O}_3$ ,  $\text{F}_2$ ,  $\text{H}_2\text{O}$ ,  $\text{Br}_2$ ,  $\text{ICl}$ ,  $\text{NaCl}$ ,  $\text{Fe}$   
Which is incorrect about the intermolecular force or forces that predominate in the above given substances.

- (A)  $\text{Al}_2\text{O}_3$ ,  $\text{NaCl}$ ,  $\text{Fe}$  - Ionic (B)  $\text{F}_2$ ,  $\text{Br}_2$  - Dispersion forces  
(C)  $\text{H}_2\text{O}$  - Hydrogen Bonding (D)  $\text{ICl}$  - Dipole-Dipole interaction

**A-2.** Match the solids in Column-I with their constituent particle in Column-II and nature of binding force between them in Column-III and Identify which is correct for these matching.

| <b>Column-I</b><br><b><u>Solid</u></b>                                                                           | <b>Column-II</b><br><b><u>Constituent particle</u></b> | <b>Column-III</b><br><b><u>Binding force</u></b> |
|------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|--------------------------------------------------|
| (a) Diamond                                                                                                      | (p) Ion                                                | (i) Metallic                                     |
| (b) Sodium Chloride                                                                                              | (q) Atom                                               | (ii) Dipole dipole                               |
| (c) $\text{HCl}$                                                                                                 | (r) Kernel                                             | (iii) Ionic                                      |
| (d) Aluminium                                                                                                    | (s) Molecule                                           | (iv) Covalent                                    |
| (e) $\text{H}_2\text{O}(\text{s})$                                                                               |                                                        | (v) H-bonding                                    |
| (f) $\text{I}_2(\text{s})$                                                                                       |                                                        | (vi) dispersion forces                           |
| (A) (a)- (q), (iv) ; (b)- (p), (iii) ; (c) - (s) , (ii) ; (d) - (r) , (i) ; (e) - (s) , (v) ; (f) -(s) , (vi)    |                                                        |                                                  |
| (B) (a)- (q), (iv) ; (b)- (p), (iii) ; (c) - (p) , (iii) ; (d) - (r) , (i) ; (e) - (s) , (v) ; (f) -(s) , (vi)   |                                                        |                                                  |
| (C) (a)- (q), (iv) ; (b)- (p), (iii) ; (c) - (p) , (iii) ; (d) - (p) , (iii) ; (e) - (s) , (v) ; (f) -(s) , (vi) |                                                        |                                                  |
| (D) (a)- (q), (iv) ; (b)- (p), (iii) ; (c) - (p) , (iii) ; (d) - (r) , (i) ; (e) - (s) , (iv) ; (f) -(s) , (vi)  |                                                        |                                                  |

**A-3.** Which of the following is/are pseudo solids ?

- I.  $\text{KCl}$  II. Barium chloridedihydrate  
III. Rubber IV. Solid cake left after distillation of coal tar  
(A) I,III (B) II, III (C) III, IV (D) only III

**A-4.** Which of the following solids are not correctly matched with the bonds found between the constituent particles:

- (A) Solid  $\text{CO}_2$  : Vanderwaal's (B) Graphite : Covalent and Vanderwaal  
(C) Grey Cast Iron : Ionic (D) Metal alloys : Ions-delocalised electrons

### Section (B) : Lattices and Lattice Parameters

**B-1.** Choose the correct statements

- (A) equivalent points in unit cells of a periodic lattice lie on a Bravais lattice  
(B) equivalent points in unit cells of a periodic lattice do not lie on a Bravais lattice  
(C) There are four Bravais lattices in two dimensions  
(D) There are five Bravais lattices in three dimensions

**B-2.** Which of the following are the correct axial distance and axial angles for rhombohedral system?

- (A)  $a = b = c$ ,  $\alpha = \beta = \gamma \neq 90^\circ$  (B)  $a = b \neq c$ ,  $\alpha = \beta = \gamma = 90^\circ$   
(C)  $a \neq b \neq c$ ,  $\alpha = \beta = \gamma = 90^\circ$  (D)  $a \neq b \neq c$ ,  $\alpha \neq \beta \neq \gamma \neq 90^\circ$

**B-3.** A unit cell having dimensions  $a \neq b \neq c$ ;  $\alpha \neq \beta \neq \gamma \neq 90^\circ$  is known as

- (A) Monoclinic (B) Triclinic (C) Rhomoboheral (D) Orthorhombic

**B-4.** A match box exhibits:

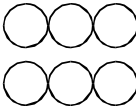
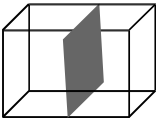
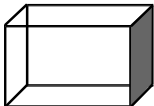
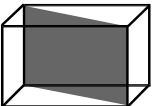
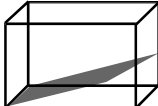
- (A) cubic geometry (B) monoclinic geometry  
(C) orthorhombic geometry (D) tetragonal geometry

## Section (C) : Unit Cell Content and Density Calculations

- C-1.** In a face centered cubic cell, the contribution of an atom at a face of the unit cell is  
(A)  $1/2$  (B) 1 (C) 2 (D) 3
- C-2.** In a face centered lattice of X and Y, X atoms are present at the corners while Y atoms are at face centers. Then the formula of the compound is :  
(A)  $XY_3$  (B)  $X_2Y_3$  (C)  $X_3Y$  (D) XY
- C-3.** In a face centered lattice of X and Y, X atoms are present at the corners while Y atoms are at face centers. Then the formula of the compound would be if two atoms of X are missing from the corners :  
(A)  $X_4Y$  (B)  $X_3Y_4$  (C)  $XY_4$  (D)  $X_2Y_4$
- C-4.** In a cubic structure of compound which is made from X and Y, where X atoms are at the corners of the cube and Y at the face centers of the cube. The molecular formula of compound is  
(A)  $X_2Y$  (B)  $X_3Y$  (C)  $XY_2$  (D)  $XY_3$
- C-5.** A solid has a structure in which W atoms are located at the corners of a cubic lattice. O atom at the center of the edges and Na atom at center of the cube. The formula for the compound is  
(A)  $NaWO_2$  (B)  $NaWO_3$  (C)  $Na_2WO_3$  (D)  $NaWO_4$
- C-6.** A compound of A and B crystallizes in a cubic lattice in which A atoms occupy the lattice points at the corners of a cube and two atoms of B occupy the center of each of the cube faces. What is the formula of this compound?  
(A)  $AB_3$  (B)  $AB_4$  (C)  $AB_2$  (D)  $AB_6$
- C-7.** An element (atomic mass = 100 g/mole) having BCC structure has unit cell edge 400 pm. The density of the element is (no. of atoms in BCC(Z) = 2).  
(A)  $2.144 \text{ g/cm}^3$  (B)  $5.2 \text{ g/cm}^3$  (C)  $7.289 \text{ g/cm}^3$  (D)  $10.376 \text{ g/cm}^3$

## Section (D) : Cubical Unit Cells and Close Packings

- D-1.** Copper crystallises in a structure of face centered cubic unit cell. The atomic radius of copper is 1.28 Å. What is axial length on an edge of copper.  
(A) 2.16 Å (B) 3.62 Å (C) 3.94 Å (D) 4.15 Å
- D-2.** If the radius of a metal atom is 2.00 Å and its crystal structure in cubic close packed (fcc lattice), what is the volume (in  $\text{cm}^3$ ) of one unit cell ?  
(A)  $8.00 \times 10^{-24}$  (B)  $1.60 \times 10^{-23}$  (C)  $1.80 \times 10^{-22}$  (D)  $2.26 \times 10^{-23}$
- D-3.** What is true about BCC unit cell ?  
(A) No. of atoms in the unit cell is 2  
(B) In addition to an atom at the centred of the body of the unit cell there are 6 atoms at 6 different corner  
(C) Packing fraction is 0.74  
(D) none of these
- D-4.** The fraction of total volume occupied by the atoms in a simple cube is  
(A)  $\frac{\pi}{4}$  (B)  $\sqrt{2} \frac{\pi}{8}$  (C)  $\sqrt{2} \frac{\pi}{6}$  (D)  $\frac{\pi}{6}$
- D-5.** Platinum crystallizes in a face-centered cubic crystal with a unit cell length 'a'. The distance between nearest neighbors is :  
(A) a (B)  $a \frac{\sqrt{3}}{2}$  (C)  $a \frac{\sqrt{2}}{2}$  (D)  $a \frac{\sqrt{2}}{4}$

- D-6.** Which one of the following schemes of ordering closed packed sheets of equal sized spheres does not generate close packed lattice :  
 (A) ABCABC (B) ABACABAC (C) ABBAABBA (D) ABCBCABCBC
- D-7.** Metallic gold crystallises in face centered cubic. Lattice with edge-length 4.070 Å. Closest distance between gold atoms is :  
 (A) 2.035 Å (B) 8.140 Å (C) 2.878 Å (D) 1.357 Å
- D-8.** Which of the following shaded plane in fcc lattice contains arrangement of atoms as shown by circles :
- 
- (A)  (B)  (C)  (D) 
- D-9.** Lithium crystallizes in a body centered cubic lattice. How many next-nearest neighbors does each Li have?  
 (A) 6 (B) 8 (C) 12 (D) 4
- D-10.\*** The co-ordination number of FCC structure for metals is 12, since  
 (A) each atom touches 4 others in same layer, 3 in layer above and 3 in layer below.  
 (B) each atom touches 4 others in same layer, 4 in layer above and 4 in layer below.  
 (C) each atom touches 6 others in same layer, 3 in layer above and 3 in layer below.  
 (D) each atom touches 3 others in same layer, 6 in layer above and 6 in layer below.
- D-11.** An element exists as hexagonal close packed structure as well as cubic closed packed structure. In which case the element would have higher density ?  
 (A) ccp (B) hcp (C) same in both (D) unpredictable
- D-12.** What is the coordination number of atoms in BCC, HCP and CCP and simple lattices.  
 (A) 8, 12, 12, 6 (B) 6, 12, 12, 8 (C) 12, 6, 8, 12 (D) 12, 12, 8, 6

## Section (E) Voids

- E-1.** If the anions (A) form 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<sub>2</sub> (C) C<sub>2</sub>A<sub>3</sub> (D) C<sub>3</sub>A<sub>2</sub>
- E-2.** In a multi layered close-packed structure  
 (A) there are twice as many tetrahedral holes as there are close-packed atoms  
 (B) there are as many tetrahedral holes as there are closed packed atoms  
 (C) there are twice as many octahedral holes as there are close-packed atoms  
 (D) there are as many tetrahedral holes as there are octahedral holes
- E-3.** In a closed packed array of N spheres, the octahedral holes are :  
 (A) N/2 (B) 2N (C) 4N (D) N
- E-4.** Match list-I with list-II and select the correct answer by using the codes given below:

| List I   |                     |
|----------|---------------------|
| (Shapes) |                     |
| (A)      | Planar triangle     |
| (B)      | Square planar       |
| (C)      | Body centered cubic |
| (D)      | Tetrahedral         |

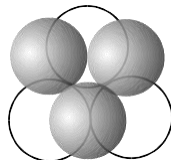
| List II        |       |
|----------------|-------|
| (Radius ratio) |       |
| 1.             | 0.732 |
| 2.             | 0.225 |
| 3.             | 0.155 |
| 4.             | 0.414 |

### Codes

|     | A | B | C | D |
|-----|---|---|---|---|
| (A) | 3 | 4 | 1 | 2 |
| (C) | 2 | 1 | 4 | 3 |

|     | A | B | C | D |
|-----|---|---|---|---|
| (B) | 3 | 2 | 1 | 4 |
| (D) | 1 | 3 | 4 | 2 |

- E-5.** If the anions (A) form hexagonal closest packing and cations (C) occupy only  $\frac{2}{3}$  octahedral voids in it, then the general formula of the compound is  
 (A) CA (B)  $CA_2$  (C)  $C_2A_3$  (D)  $C_3A_2$
- E-6.** A solid is formed and it has three types of atoms X, Y, Z. X forms a FCC lattice with Y atoms occupying all the tetrahedral voids and Z atoms occupying half the octahedral voids. The formula of the solid is:  
 (A)  $X_2Y_4Z$  (B)  $XY_2Z_4$  (C)  $X_4Y_2Z$  (D)  $X_4YZ_2$
- E-7.** The empty space between the shaded balls and hollow balls as shown in the diagram is called



- (A) hexagonal void (B) octahedral void (C) tetrahedral void (D) double triangular void

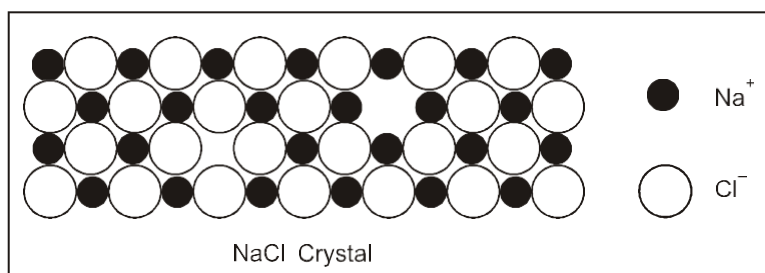
## Section : (F) Ionic Solids

- F-1.** For an ionic solid of the general formula AB and coordination number 6, the value of the radius ratio will be  
 (A) less than 0.225 (B) in between 0.225 and 0.414  
 (C) between 0.414 and 0.732 (D) greater than 0.732
- F-2.** The radius of  $Ag^+$  ion is 126 pm and that of  $I^-$  ion is 216 pm. The co-ordination number of  $Ag^+$  ion is.  
 (A) 2 (B) 4 (C) 6 (D) 8
- F-3.** The spinel structure ( $AB_2O_4$ ) consists of an fcc array of  $O^{2-}$  ions in which the :  
 (A) A cation occupies one-eighth of the tetrahedral holes and B cation occupies one-half of octahedral holes  
 (B) A cation occupies one-fourth of the tetrahedral holes and the B cations the octahedral holes  
 (C) A cation occupies one-eighth of the octahedral hole and the B cation the tetrahedral holes  
 (D) A cation occupies one-fourth of the octahedral holes and the B cations the tetrahedral holes
- F-4.** An ionic solid of XY type having anions in CCP lattice and cations in the octahedral voids. Let a be the edge length of an FCC cube. The radius ratio of cation( $R_+$ ) to that of anion( $R_-$ ) is greater than 0.415. Then which of the following is false:  
 (A)  $R_+ = \frac{a}{2\sqrt{2}}$  (B)  $R_+ + R_- = \frac{a}{2}$   
 (C) Anions will not be in contact with each other. (D) Cations will not be in contact with each other.
- F-5.** How many units cells are there in 1.00 g cube shaped ideal crystal of AB ( $M_w = 60$ ) which has a NaCl type lattice  
 (A)  $6.02 \times 10^{23}$  (B)  $1.00 \times 10^{22}$  (C)  $2.50 \times 10^{21}$  (D)  $6.02 \times 10^{24}$
- F-6.** The density of  $CaF_2$  (fluorite structure) is  $3.18 \text{ g/cm}^3$ . The length of the side of the unit cell is  
 (A) 253 pm (B) 344 pm (C) 546 pm (D) 273 pm
- F-7.** Which of the following statements is correct in the rock-salt structure of an ionic compounds?  
 (A) coordination number of cation is four whereas that of anion is six.  
 (B) coordination number of cation is six whereas that of anion is four.  
 (C) coordination number of each cation and anion is four.  
 (D) coordination number of each cation and anion is six.
- F-8.** The coordination number of cation and anion in Fluorite  $CaF_2$  and CsCl are respectively  
 (A) 8:4 and 6:3 (B) 6:3 and 4:4 (C) 8:4 and 8:8 (D) 4:2 and 2:4

- F-9.** An ionic compound AB has ZnS type structure. If the radius  $A^+$  is 22.5 pm, then the ideal radius of  $B^-$  would be  
 (A) 54.35 pm (B) 100 pm (C) 145.16 pm (D) none of these
- F-10.**  $NH_4Cl$  crystallizes in a body-centered cubic type lattice with a unit cell edge length of 387 pm. The distance between the oppositely charged ions in the lattice is  
 (A) 335.1 pm (B) 83.77 pm (C) 274.46 pm (D) 137.23 pm
- F-11.** The tetrahedral voids formed by ccp arrangement of  $Cl^-$  ions in rock salt structure are  
 (A) Occupied by  $Na^+$  ions (B) Occupied by  $Cl^-$  ions  
 (C) Occupied by either  $Na^+$  or  $Cl^-$  ions (D) Vacant
- F-12.** Which of the following expressions is correct in the case of a sodium chloride unit cell (edge length = a)  
 (A)  $r_c + r_a = a/2$  (B)  $r_c + r_a = a$  (C)  $r_c + r_a = 2a$  (D)  $r_c + r_a = 2^{1/2} a$
- F-13.** MgO exist in a rock-salt type unit cell. Each  $Mg^{+2}$  ion will be in contact with  
 (A)  $4O^{-2}$  ions (B)  $6O^{-2}$  ions (C)  $8O^{-2}$  ions (D)  $2O^{-2}$  ions
- F-14.\*** Which of the following crystals have 8 : 8 coordination ?  
 (A)  $NH_4Cl$  (B) AlFe (C) MnO (D)  $NH_4Br$
- F-15.\*** Which of the following crystals have 6 : 6 coordination ?  
 (A)  $NH_4I$  (B) MgO (C) MnO (D) ZnS

### Section (G) : Crystal Defects

- G-1.** Type of defect shown in figure :



- (A) Frenkle (B) Schottky  
 (C) Non Stoichiometric (D) F-Centre
- G-2.** Type of defect shown in the given NaCl crystal is :
- 
- NaCl Crystal
- (A) Frenkle (B) F-centre (C) Metal excess (D) Edge dislocation
- G-3.** BaO has a rock-salt type structure. When subjected to high pressure, the ratio of the coordination number of  $Ba^{+2}$  ion to  $O^{-2}$  changes to  
 (A) 4 : 8 (B) 8 : 4 (C) 8 : 8 (D) 4 : 4

- G-4.** Cesium chloride on heating to 760 K changes into  
 (A) CsCl(g) (B) NaCl structure (C) antifluorite structure (D) ZnS structure
- G-5.** The ionic radii of  $\text{Rb}^+$  and  $\text{I}^-$  are 1.46 and 2.16 Å. The most probable type of structure exhibited by it is  
 (A) CsCl type (B) NaCl type (C) ZnS type (D)  $\text{CaF}_2$  type
- G-6.** What type of crystal defect is indicated in the diagram below ?  

|               |               |               |               |               |               |
|---------------|---------------|---------------|---------------|---------------|---------------|
| $\text{Na}^+$ | $\text{Cl}^-$ | $\text{Na}^+$ | $\text{Cl}^-$ | $\text{Na}^+$ | $\text{Cl}^-$ |
| $\text{Cl}^-$ | y             | $\text{Cl}^-$ | $\text{Na}^+$ | y             | $\text{Na}^+$ |
| $\text{Na}^+$ | $\text{Cl}^-$ | y             | $\text{Cl}^-$ | $\text{Na}^+$ | $\text{Cl}^-$ |
| $\text{Cl}^-$ | $\text{Na}^+$ | $\text{Cl}^-$ | $\text{Na}^+$ | y             | $\text{Na}^+$ |

 (A) Frenkel defect (B) Schottky defect  
 (C) Interstitial defect (D) Frenkel and Schottky defect
- G-7.** In the Schottky defect:  
 (A) cations are missing from the lattice sites and occupy the interstitial sites  
 (B) equal number of cations and anions are missing  
 (C) anion are missing and electrons are present in their place  
 (D) equal number of extra cations and electrons are present in the interstitial sites
- G-8.** A crystal of NaCl, which has sodium ions and chloride ions missing from the lattice point, is said to exhibit  
 (A) Surface defect (B) Lattice defect (C) Frenkel defect (D) Schottky defect
- G-9.** F-centers are  
 (A) the electrons trapped in anionic vacancies  
 (B) the electrons trapped in cation vacancies  
 (C) non-equivalent sites of stoichiometric compound  
 (D) all of the above

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## PART - II : MISCELLANEOUS QUESTIONS

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### Comprehensions Type

#### Comprehension # 1

In HCP or CCP, constituent particles occupy 74% of the available space. The remaining space (26%) in between the spheres, remains unoccupied and is called interstitial voids or holes. Considering the close packing arrangement, each sphere in the second layer rests on the hollow space of the first layer, touching each other. The void created is called tetrahedral void. If  $R$  is the radius of the sphere in the close packed arrangement, then

$$r \text{ (radius of tetrahedral void)} = 0.225 R$$

In a close packing arrangement, the interstitial void formed by the combination of two triangular voids of the first and second layer is called octahedral void. Thus, double triangular void is surrounded by six spheres. The centre of these sphere on joining, forms octahedron. If  $R$  is the radius of the sphere in a close packed arrangement, then

$$r \text{ (radius of octahedral void)} = 0.414 R.$$

- If the anions (A) form hexagonal close packing and cations (B) occupy only  $\frac{2}{3}$ rd octahedral voids in it, then the general formula of the compound is  
 (A) AB (B)  $\text{A}_3\text{B}_2$  (C)  $\text{A}_2\text{B}$  (D)  $\text{AB}_2$
- If the spinel structure, oxide ions are cubic close whereas  $\frac{1}{8}$ th of tetrahedral voids are occupied by  $\text{A}^{2+}$  cations and  $\frac{1}{2}$  of octahedral voids are occupied by  $\text{B}^{3+}$  cations. The general formula of the compound having spinel structure is:  
 (A)  $\text{A}_2\text{B}_2\text{O}_4$  (B)  $\text{AB}_2\text{O}_4$  (C)  $\text{A}_2\text{B}_4\text{O}_2$  (D)  $\text{A}_4\text{B}_2\text{O}_2$

## Comprehension # 2

Calcium crystallizes in a cubic unit cell with density 3.2 g/cc. Edge-length of the unit cell is 437 picometre (pm)

3. The type of unit cell is  
(A) Simple cubic (B) BCC (C) FCC (D) Edge-centred
4. The nearest neighbour distance is  
(A) 154.5 pm (B) 309 pm (C) 218.5 pm (D) 260 pm
5. The number of nearest neighbours of a Ca atom are  
(A) 4 (B) 6 (C) 8 (D) 12
6. If the metal is melted, density of the molten metal was found to be 3 g/cc. What will be the percentage of empty space in the melt?  
(A) 31% (B) 36% (C) 28% (D) 49%

## Comprehension # 3

When an atom or an ion is missing from its normal lattice site, a lattice vacancy (Schottky defect) is created. In stoichiometric ionic crystals, a vacancy of one ion has to be accompanied by the vacancy of the oppositely charged ion in order to maintain electrical neutrality.

In a Frenkel defect an ion leaves its position in the lattice and occupies an interstitial void. This is the Frenkel defect commonly found along with the Schottky defects and interstitials. In pure alkali halides, Frenkel defects are not found since the ions cannot get into the interstitial sites. Frenkel defects are found in silver halides because of the small size of the  $\text{Ag}^+$  ion. Unlike Schottky defects, Frenkel defects do not change the density of the solids. In certain ionic solids (e.g.  $\text{AgBr}$ ) both Schottky and Frenkel defects occur. The defects discussed above do not disturb the stoichiometry of the crystalline material. There is large variety of non-stoichiometric inorganic solids which contain an excess or deficiency of one of the elements. Such solids showing deviations from the ideal stoichiometric composition form an important group of solids. For example in the vanadium oxide,  $\text{VO}_x$ ,  $x$  can be anywhere between 0.6 and 1.3. There are solids which are difficult to prepare in the stoichiometric composition. Thus, the ideal composition in compounds such as  $\text{FeO}$  is difficult to obtain (normally we get a composition of  $\text{Fe}_{0.95}\text{O}$  but it may range from  $\text{Fe}_{0.93}\text{O}$  to  $\text{Fe}_{0.96}\text{O}$ ). Non-stoichiometric behaviour is most commonly found for transition metal compounds though is also known for some lanthanoids and actinoids.

Zinc oxide loses oxygen reversibly at high temperatures and turns yellow in colour. The excess metal is accommodated interstitially, giving rise to electrons trapped in the neighbourhood. the enhanced electrical conductivity of the non-stoichiometric  $\text{ZnO}$  arises from these electrons.

Anion vacancies in alkali halides are produced by heating the alkali halide crystals in an atmosphere of the alkali metal vapour. When the metal atoms deposit on the surface they diffuse into the crystal and after ionisation the alkali metal ion occupies cationic vacancy whereas electron occupies anionic vacancy. Electrons trapped in anion vacancies are referred to as F-centers (from Farbe the German word for colour) that gives rise to interesting colour in alkali halides. Thus, the excess of potassium in  $\text{KCl}$  makes the crystal appear violet and the excess of lithium in  $\text{LiCl}$  makes it pink.

7. When  $\text{LiCl}$  is heated into the vapour of lithium, the crystal acquires pink colour. This is due to  
(A) Schottky defects (B) Frenkel defects  
(C) Metal excess defect leading to F-centers (D) Electronic defect
8. Strongly heated  $\text{ZnO}$  crystal can conduct electricity. This is due to  
(A) Movement of extra  $\text{Zn}^{2+}$  ions present in the interstitial sites  
(B) Movement of electrons in the anion vacancies  
(C) Movement of both  $\text{Zn}^{2+}$  ions and electrons  
(D) None of these
9.  $\text{AgCl}$  is crystallized from molten  $\text{AgCl}$  containing a little  $\text{CdCl}_2$ . The solid obtained will have  
(A) cationic vacancies equal to number of  $\text{Cd}^{2+}$  ions incorporated  
(B) cationic vacancies equal to double the number of  $\text{Cd}^{2+}$  ions  
(C) anionic vacancies  
(D) neither cationic nor anionic vacancies
10. Which of the following is most appropriate crystal to show Frenkel defect.  
(A)  $\text{CsCl}$  (B)  $\text{NaCl}$  (C)  $\text{AgBr}$  (D)  $\text{CaCl}_2$

## Match the column

11. **Column I** **Column II**
- |                                         |                                                                          |
|-----------------------------------------|--------------------------------------------------------------------------|
| (A) simple cubic and face-centred cubic | (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 $90^\circ$                  |
| (D) hexagonal and monoclinic            | (s) belong to same crystal system                                        |

12. **Column I** **Column II**  
[Distance in terms of edge length of cube (a)]
- |             |                                                                       |
|-------------|-----------------------------------------------------------------------|
| (A) 0.866 a | (p) Shortest distance between cation & anion in CsCl structure.       |
| (B) 0.707 a | (q) Shortest distance between two cation in $\text{CaF}_2$ structure. |
| (C) 0.433 a | (r) Shortest distance between carbon atoms in diamond.                |
|             | (s) Shortest distance between two cations in rock salt structure.     |

13. Match the column:

- | <b>Column I</b>          | <b>Column II</b>                                               |
|--------------------------|----------------------------------------------------------------|
| (A) Rock salt structure  | (p) Co-ordination number of cation is 4                        |
| (B) Zinc Blend structure | (q) $\frac{\sqrt{3}a}{4} = r_+ + r_-$                          |
| (C) Fluorite structure   | (r) Co-ordination number of cation and anion are same          |
|                          | (s) Distance between two nearest anion is $\frac{a}{\sqrt{2}}$ |

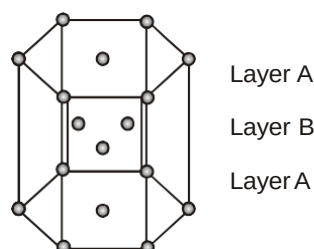
## Assertion / Reasoning Type

14. **Statement-1** : Increase in dielectric constant is observed in Frenkel defect.  
**Statement-2** : Anions come in interstitial space in case of Frenkel defect.
- (A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1  
 (B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.  
 (C) Statement-1 is true, statement-2 is false.  
 (D) Statement-1 is false, statement-2 is true.
15. **Statement-1** : Distance between nearest lattice points in BCC is greater than the same in FCC for the atoms of comparable size.  
**Statement-2** : FCC has greater packing efficiency than BCC.
- (A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1  
 (B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.  
 (C) Statement-1 is true, statement-2 is false.  
 (D) Statement-1 is false, statement-2 is true.

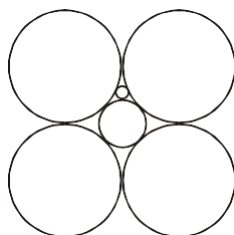
16. **Statement-1** : ZnO becomes yellow when it is heated.  
**Statement-2** : NaCl becomes yellow when heated in the presence of Na vapours due to anion vacancy.  
 (A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1  
 (B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.  
 (C) Statement-1 is true, statement-2 is false.  
 (D) Statement-1 is false, statement-2 is true.
17. **Statement-1** : In Frenkel defect in an ionic crystal, an ion is displaced from its normal site to an interstitial site.  
**Statement-2** : There is both a vacancy and an interstitial ion.  
 (A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1  
 (B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.  
 (C) Statement-1 is true, statement-2 is false.  
 (D) Statement-1 is false, statement-2 is true.

### True / False Type

18. Crystalline solids are isotropic.
19. Packing fraction of FCC and HCP units cells are same.
20. The minimum void fraction for any unit cell in any shape having only one type of atom and all voids unfilled is 0.26.
21. The location of tetrahedral voids in FCC unit cell are the centers of 8 minicubes forming a large cube.
22. Effective number of octahedral voids in a unit cell is equal to the effective number of atoms in the unit cell.
23. A metallic element crystallises into a lattice containing a sequence of layers of AB AB AB ..... Any packing of spheres leaves out voids in the lattice 26% percent by volume of this lattice is empty space.
24. Number of next neighbours of  $\text{Cs}^+$  ion in CsCl structure is 6  $\text{Cs}^+$  ions.
25. A crystal has A ions at the cube corners and B ions at the edge centers. The coordination numbers of A and B are respectively 6 and 2.
26. Distance between cation and its next neighbour in ZnS (zinc blende) is  $1/4$  of the length of body diagonal.
27. In the unit cell of HCP structure the three atoms shown in layer B are completely inside the unit cell.



28. In the configuration shown the size of the smallest circle is  $\left(\frac{2}{\sqrt{3}} - 1\right)$  times the size of the biggest circles.



### Fill in the blanks

29. The relation between edge length (a) and radius of atom (r) for BCC lattice is\_\_\_\_\_.
30. ABCABC ..... layering pattern is called\_\_\_\_\_packing, found in\_\_\_\_\_lattice.
31. ABABAB.....layering pattern is called\_\_\_\_\_packing , found in\_\_\_\_\_lattice.
32. Anions would be in contact with each other only if the cation to anion radius for a given co-ordination number is\_\_\_\_\_.
33. The number of tetrahedral voids in hexagonal primitive unit cell is\_\_\_\_\_.
34. The limiting radius for co-ordination number 8 is\_\_\_\_\_.
35. For cesium chloride structure, the interionic distance (in terms of edge length, a) is equal to\_\_\_\_\_.
36. Density of a crystal\_\_\_\_due to Schottky defect and\_\_\_\_due to Frankel defect.
37. In cubic crystal, there are\_\_\_\_\_elements of symmetry.
38. The crystal structure of CsCl is\_\_\_\_\_.
39. A spinel is an important class of oxides consisting of two types of metal ions with the oxides 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  $\text{Zn}^{2+}$ ,  $\text{Al}^{3+}$  and  $\text{O}^{2-}$  with  $\text{Zn}^{2+}$  in the tetrahedral holes. The formula of the spinel is\_\_\_\_\_.

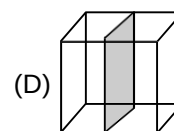
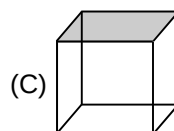
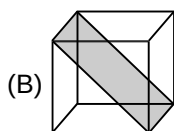
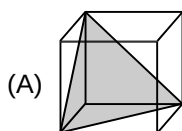
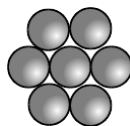
## EXERCISE # 2

### PART - I : MIXED OBJECTIVE

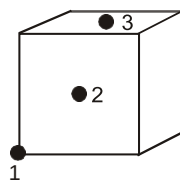
#### Single Choice type

- Platinum crystallises in a face centered cube crystal with a unit cell length of 3.9231 Å. The density and atomic radius of platinum are respectively. [Atomic mass of Pt = 195]  
(A) 45.25 g. cm<sup>-3</sup>, 2.516 Å (B) 21.86 g. cm<sup>-3</sup>, 1.387 Å  
(C) 29.46 g. cm<sup>-3</sup>, 1.48 Å (D) None of these
- Given an alloy of Cu, Ag and Au in which Cu atoms constitute the CCP arrangement. If the hypothetical formula of the alloy is Cu<sub>4</sub>Ag<sub>3</sub>Au. What are the probable locations of Ag and Au atoms.  
(A) Ag - all Tetrahedral voids; Au - all Octahedral voids  
(B) Ag - 3/8th Tetrahedral voids; Au - 1/4th Octahedral voids  
(C) Ag - 1/2 Octahedral voids; Au - 1/2 Tetrahedral voids  
(D) Ag - all Octahedral voids; Au - all tetrahedral voids
- 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 radius of carbon atom is  
(A) 77.07 pm (B) 154.14 pm (C) 251.7 pm (D) 89 pm
- A mineral having the formula AB<sub>2</sub>, crystallises in the cubic close - packed lattice, with the A atoms occupying the lattice points. The co-ordination number of the A atoms, that of B atoms and the fraction of the tetrahedral sites occupied by B atoms are  
(A) 8, 4, 100% (B) 2, 6, 75% (C) 3, 1, 25% (D) 6, 6, 50%
- Correct statement for ccp is :  
(A) Each octahedral void is surrounded by 6 spheres and each sphere is surrounded by octahedral voids  
(B) Each octahedral void is surrounded by 6 spheres and each sphere is surrounded by 6 octahedral voids  
(C) Each octahedral void is surrounded by 6 spheres and each sphere is surrounded by 8 octahedral voids  
(D) Each octahedral void is surrounded by 6 spheres and each sphere is surrounded by 12 octahedral voids
- If the radii of A<sup>+</sup> and B<sup>-</sup> are 95 pm and 181 pm respectively, then the coordination number of A<sup>+</sup> will be ?  
(A) 12 (B) 8 (C) 6 (D) 4
- The coordination number of cation and anion in Fluorite CaF<sub>2</sub> and Rutile TiO<sub>2</sub> are respectively :  
(A) 8 : 4 and 6 : 3 (B) 6 : 3 and 4 : 4 (C) 6 : 6 and 8 : 8 (D) 4 : 2 and 2 : 4
- The distance between adjacent, oppositely charged ions in rubidium chloride is 3.285 Å; in potassium chloride is 3.139 Å; in sodium bromide is 2.981 Å and in potassium bromide is 3.293 Å. The distance between adjacent oppositely charged ions in rubidium bromide is  
(A) 3.147 Å (B) 3.385 Å (C) 3.393 Å (D) 3.439 Å
- Edge length of M<sup>+</sup>X<sup>-</sup> (fcc structure) is 7.2 Å. Assuming M<sup>+</sup> – X<sup>-</sup> contact along the cell edge, radius of X<sup>-</sup> ion is ( r<sub>M<sup>+</sup></sub> = 1.6 Å ) :  
(A) 2.0 Å (B) 5.6 Å (C) 2.8 Å (D) 38 Å
- The density of KBr is 2.75 g cm<sup>-3</sup> and length of the unit cell is 654 pm (K = 39 and Br = 80) then what is true about the predicted nature of the solid.  
(A) Solid has fcc system with Z = 4 (B) Solid has simple cubic system with Z = 4  
(C) Solid has bcc system will Z = 3 (D) Solid has bcc system with Z = 2

11. The density of KCl is  $1.9893 \text{ g. cm}^{-3}$  and the length of a side of unit cell is  $6.29082 \text{ \AA}$ . The value of Avogadro's number is  
 (A)  $6.017 \times 10^{23}$  (B)  $6.023 \times 10^{23}$  (C)  $6.03 \times 10^{23}$  (D)  $6.017 \times 10^{19}$
12. In NaCl if  $r_{\text{Na}^+} = 100 \text{ pm}$ , then maximum size of  $r_{\text{Cl}^-}$  will be :  
 (A)  $241.5 \text{ pm}$  (B)  $261.5 \text{ pm}$  (C)  $251.5 \text{ pm}$  (D)  $271.5 \text{ pm}$
13. Antifluorite structure is derived from fluorite structure by :  
 (A) heating fluorite crystallattice  
 (B) subjecting fluorite structure to high pressure  
 (C) Inter changing the positions of positive and negative ions in the lattice  
 (D) none of these
14. In a solid lattice, the cation has left a lattice site and is located at interstitial position, the lattice defect is :  
 (A) interstitial defect (B) vacancy defect (C) Frenkel defect (D) Schottky defect
15. A piece of copper and another of Ge are cooled from room temperature to  $80 \text{ K}$ . The resistance of:  
 (A) each of them increases (B) Cu increases and that of Ge decreases  
 (C) Cu decreases and that of Ge increases (D) each of them decreases
16. Zinc sulphide exists in two different forms-zinc blende and wurtzite. Both occur as 4:4 co-ordination compounds. Choose the correct option from among the following :  
 (A) zinc blende has a bcc structure and wurtzite an fcc structure  
 (B) zinc blende has an fcc structure and wurtzite an hcp structure  
 (C) zinc blende as well as wurtzite have a hcp structure  
 (D) zinc blende as well as wurtzite have a ccp structure
17. Choose the correct matching sequence from the possibilities given  
 (a) Crystal defect (1) AB AB AB .....type crystal  
 (b) hcp (2) Covalent crystal  
 (c) CsCl (3) Frenkel  
 (d) Diamond (4) Face centered in cube  
 (e) NaCl (5) Simple cubical lattice
- |     | (a) | (b) | (c) | (d) | (e) | (a) | (b) | (c) | (d) | (e) |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| (A) | 3   | 1   | 2   | 5   | 4   | (B) | 3   | 1   | 5   | 2   |
| (C) | 3   | 5   | 1   | 2   | 4   | (D) | 5   | 3   | 4   | 2   |
18. In hcp (ABAB...) and ccp (ABCABC...) structures made up of spheres of equal size, the volume occupied per sphere (including the empty spaces) is ( $a = \text{radius of sphere}$ ) :  
 (A)  $5.66 a^3$  (B)  $1.33 a^3$  (C)  $2.66 a^3$  (D)  $7.40 a^3$
19. In an f.c.c. crystal, which of the following shaded planes contains the following type of arrangement of atoms?

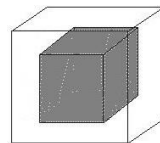


20. Given that interionic distance in  $\text{Na}^+ \text{F}^-$  crystal is  $2.31 \text{ \AA}$ , which of the following predictions will be wrong  
 (A)  $r_{\text{Na}^+} + r_{\text{F}^-} \approx 0.7$   
 (B) coordination number of  $\text{Na}^+$  = coordination number of  $\text{F}^- = 6$   
 (C)  $\text{Na}^+ \text{F}^-$  must have rock salt type crystal structure  
 (D) effective nuclear charge for  $\text{Na}^+$  and  $\text{F}^-$  are equal
21. The number of atoms in 100 g of an FCC crystal with density  $d = 10 \text{ g cm}^{-3}$  and cell edge of  $200 \text{ pm}$  is equal to :  
 (A)  $3 \times 10^{25}$  (B)  $5 \times 10^{24}$  (C)  $1 \times 10^{25}$  (D)  $2 \times 10^{25}$
22. In a face centered lattice of X and Y, X atoms are present at the corners while Y atoms are at face centers. Then the formula of the compound would be if one of the X atoms is missing from a corner in each unit cell  
 (A)  $\text{X}_7\text{Y}_{24}$  (B)  $\text{X}_{24}\text{Y}_7$  (C)  $\text{XY}_{24}$  (D)  $\text{X}_{24}\text{Y}$
23. Aluminum metal has a density of  $2.72 \text{ g cm}^{-3}$  and crystallizes in a lattice with an edge length of  $404 \text{ pm}$ . Which of the following alternatives are correct  
 (A) it forms a base centered cubic unit cell (B) it forms a face centered cubic unit cell  
 (C) its coordination number is 8 (D) its coordination number is 6
24. Consider a Body Centered Cubic (BCC) arrangement, let  $d_e$ ,  $d_{fd}$ ,  $d_{bd}$  be the distances between successive atoms located along the edge, the face-diagonal, the body diagonal respectively in a unit cell. Their order is given by:  
 (A)  $d_e < d_{fd} < d_{bd}$  (B)  $d_{fd} > d_{bd} > d_e$  (C)  $d_{fd} > d_e > d_{bd}$  (D)  $d_{bd} > d_e > d_{fd}$
25. Figure shows a cube of unit cell of CCP arrangement with face centered atoms marked 1, 2, 3. Which of the following statements is true.



- (A) Atom 3 is twice as far from 1 as from 2 (B) Atom 2 is equidistant from atoms 1 & 3.  
 (C) Atom 2 is nearer to 1 than to 3. (D) All atoms lie on a right angled triangle.
26. Consider a cube 1 of Body Centered Cubic unit cell of edge length  $a$  now atom at the body center can be viewed to be lying on the corner of another cube 2. Find the volume common to cube 1 and cube 2.  
 (A)  $\frac{a^3}{27}$  (B)  $\frac{a^3}{64}$  (C)  $\frac{a^3}{2\sqrt{2}}$  (D)  $\frac{a^3}{8}$
27. You are given 6 identical balls. What is the maximum number of square voids and triangular voids (in separate arrangements) that can be created (balls are to be arranged in one plane)?  
 (A) 2, 4 (B) 4, 2 (C) 4, 3 (D) 3, 4
28.  $\text{MgAl}_2\text{O}_4$  is found in the Spinel structure in which  $\text{O}^{2-}$  ions constitute CCP lattice,  $\text{Mg}^{2+}$  ions occupy  $1/8$ th of the Tetrahedral voids and  $\text{Al}^{3+}$  ions occupy  $1/2$  of the Octahedral voids. Find the total +ve charge contained in one unit cell.  
 (A)  $+7/4$  electronic charge (B)  $+6$  electronic charge  
 (C)  $+2$  electronic charge (D)  $+8$  electronic charge
29. Which of the following statements are correct in context of point defects in a crystal ?  
 (A)  $\text{AgCl}$  has anion Frenkel defect and  $\text{CaF}_2$  has Schottky defects  
 (B)  $\text{AgCl}$  has cation Frenkel defects and  $\text{CaF}_2$  has anion Frenkel defects  
 (C)  $\text{AgCl}$  as well as  $\text{CaF}_2$  have anion Frenkel defects  
 (D)  $\text{AgCl}$  as well as  $\text{CaF}_2$  has Schottky defects

30. In an FCC unit cell a cube is formed by joining the centers of all the tetrahedral voids to generate a new cube. Then the new cube would contain voids as :
- (A) 1 full Tetrahedral void, 1 full Octahedral void  
 (B) 1 full Tetrahedral void only  
 (C) 8 full Tetrahedral voids and 1 full Octahedral void  
 (D) 1 full Octahedral void only



31. There are three ionic compounds, first compound has fcc lattice of anions and cations are present in all tetrahedral voids, second compound has fcc lattice of anions and cations are present in all octahedral voids and third compound has simple cubical lattice in which cubical void is occupied by cation, then the order of packing efficiency of these will be
- (A) I > II > III                      (B) II > I > III                      (C) III > II > I                      (D) III > I > II
32. Strontium chloride has a fluorite structure, which of the following statement is true for the structure of strontium chloride ?
- (A) the strontium ions are in a body-centered cubic arrangement  
 (B) the strontium ions are in a face-centered cubic arrangement  
 (C) each chloride ion is at the center of a cube of 8 strontium ions  
 (D) each strontium ion is at the center of a tetrahedron of 4 chloride ions
33. Zinc Oxide, white in colour at room temperature, acquires yellow colour on heating due to:
- (A) Zn being a transition element  
 (B) paramagnetic nature of the compound  
 (C) trapping of electrons at the site vacated by Oxide ions  
 (D) Both (A) & (B)
34. NaCl shows Schottky defects and AgCl Frenkel defects. Their electrical conductivity is due to :
- (A) motion of ions and not the motion of electrons  
 (B) motion of electrons and not the motion of ions  
 (C) lower co-ordination number of NaCl  
 (D) higher co-ordination number of AgCl

### Multiple Choice type

35. Lead has a density of  $11.34 \text{ g/cm}^3$  and crystallizes in a face-centered lattice. Choose the correct alternatives
- (A) the volume of one unit cell is  $1.214 \times 10^{-22} \text{ cm}^3$   
 (B) the volume of one unit cell is  $1.214 \times 10^{-19} \text{ cm}^3$   
 (C) the atomic radius of lead is 175 pm  
 (D) the atomic radius of lead is 155.1 pm
36. The ionic radii of Cs<sup>+</sup> and Cl<sup>-</sup> are 0.165 nm and 0.181 nm respectively. Their atomic weights are 133 and 35.5. Then,
- (A) the lattice parameter (a) is 0.4 nm  
 (B) the lattice parameter can not be determined from this data  
 (C) the density of CsCl is  $4.37 \times 10^3 \text{ kg/m}^3$   
 (D) the CsCl structure has a fcc structure on the basis of given information.
37. Which of the following statement (s) is/are correct ?
- (A) The coordination number of each type of ion 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. ( $r_{\text{Na}^+} = 95 \text{ pm}$  ;  $r_{\text{Cl}^-} = 181 \text{ pm}$ )
38. Which of the following is/are correct ?
- (A) Schottky defect lowers the density  
 (B) Frenkel defect increases the dielectric constant of the crystals  
 (C) Stoichiometric defects make the crystals electrical conductors  
 (D) In the Schottky defect, equal number of extra cations and electrons are present in the interstitial sites

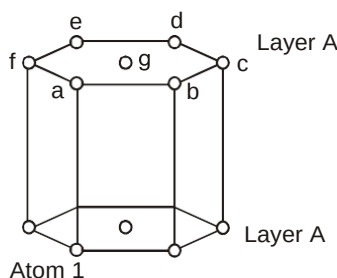
39. Which of the following statement(s) for crystal having schottky defect is/are correct.  
 (A) Schottky defect arises due to absence of cations & anion from positions which they are expected to occupy.  
 (B) The density of crystal having shottky defect is smaller than that of perfect crystal.  
 (C) Schottky defect are more common in co-valent compound with higher co-ordination number.  
 (D) The crystal having shottky defect is electrically neutral as a whole.
40. Which statements is/are true about HCP and CCP lattice  
 (A) Number of tetrahedral voids are twice of octahedral holes  
 (B) 12 tetrahedral and 6 octahedral voids are present in one HCP unit cell  
 (C) C.N. of HCP unit cell is 12  
 (D) If atom of tetrahedral voids displace into octahedral voids then it is Schootky defect.
41. Given that interionic distance in  $\text{Na}^+ \text{F}^-$  crystal is  $2.31\text{\AA}$  and  $r_{\text{F}^-} = 1.36\text{\AA}$ , which of the following predictions will be right  
 (A)  $r_{\text{Na}^+} r_{\text{F}^-} \approx 0.7$   
 (B) coordination number of  $\text{Na}^+$  = coordination number of  $\text{F}^- = 6$   
 (C)  $\text{Na}^+ \text{F}^-$  will have rock salt type crystal structure  
 (D) effective nuclear charge for  $\text{Na}^+$  and  $\text{F}^-$  are equal

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## PART - II : SUBJECTIVE QUESTIONS

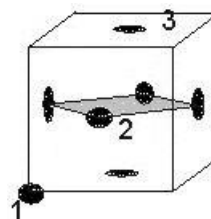
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- Silver crystallizes in cubic lattice. The density is found to be  $10.7 \text{ kg/dm}^3$ . If the unit cell length is  $4.06\text{\AA}$ , find the unit cell type.
- A compound formed by elements X & Y, Crystallizes in a cubic structure, where X is at the corners of the cube and Y is at six face centers. What is the formula of the compound? If side length is  $5\text{\AA}$ , estimate the density of the solid assuming atomic weight of X and Y as 60 and 90 respectively.
- The metal nickel crystallizes in a face centred cubic structure. Its density is  $8.9 \text{ gm/cm}^3$ . Calculate  
 (a) the length of the edge of the unit cell.  
 (b) the radius of the nickel atom. [Atomic weight of Ni = 58.89]
- Four identical spheres of radius  $r$  are arranged such that centers of three of them form an equilateral triangle and the fourth one rests symmetrically above the triangle touching all of them. Find :  
 (i) The area of the triangle thus formed.  
 (ii) Perpendicular distance between the triangle and the center of the fourth atom.  
 (iii) Are all the balls identical in the arrangement ?
- Consider a corner atom of 1st layer of an HCP unit cell showing alternate AA layers. Find  
 (i) Find identical atoms (III layer) with respect to the distances from the atom 1.  
 (ii) Arrange the distances in ascending order.



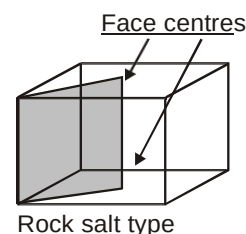
6. In a face centered lattice of X and Y, X atoms are present at the corners while Y atoms are at face centers,  
 (a) What is the formula of the compound?  
 (b) What would be the formula of the compound if  
 (i) one of the X atoms is missing from a corner in each unit cell  
 (ii) two atoms of X are missing from the corners,  
 (iii) one of the X atoms from a corner is replaced by Z atoms (also monovalent) ?

7. Following figure shows an FCC unit cell with atoms of radius  $r$  marked 1(corner), 2(face center), 3(face center). A quadrilateral is also shown by joining the centers of 4 face centered atoms.  
 Find : (i) The distances between atoms 1&2, 2&3 and 1&3.  
 (ii) The shape and dimensions of the quadrilateral.



8. A solid  $A^+B^-$  has NaCl type close packed structure. If the anion has a radius of 241.5 pm, what should be the minimum radius of the cation ? Can a cation  $C^+$  having radius of 50 pm be fitted into the tetrahedral hole of the crystal  $A^+B^-$  ?
9. In a crystalline solid, anions B are arranged in a cubic close packing. Cations A are equally distributed between octahedral and tetrahedral voids. If all the octahedral voids are occupied, what is the formula of the solid ?
10. In corundum, oxide ions are arranged in hexagonal close packing and aluminium ions occupy two-third of the octahedral voids. What is the formula of corundum ?
11. The two ions  $A^+$  and  $B^-$  have radii 88 and 200 pm respectively. In the close packed crystal of compound AB, predict the co-ordination number of  $A^+$ .
12. A small sphere of radius  $10\text{\AA}$  was found to fit perfectly in the largest void of Simple Cubic arrangement. Find the location of the sphere and the volume of the unit cell.
13. A spinel is an important class of oxides consisting of two types of metal ions with the oxides 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  $Zn^{2+}$ ,  $Al^{3+}$  and  $O^{2-}$  with  $Zn^{2+}$  in the tetrahedral holes. Give formula of the spinel.

14. In Rock Salt type structure cations(radius  $r$ ) occupy Octahedral holes in the FCC of anions(radius  $R$ ) such that there is no distortion in the FCC lattice. Find the perimeter of the shaded region.



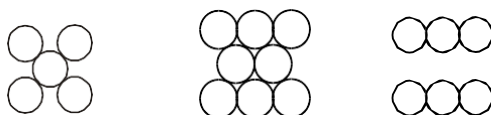
15. Try to answer the following:  
 (i) In Zinc Blende structure there is one  $Zn^{+2}$  ion per  $S^{2-}$  ion. But the radius ratio lies in the range of Tetrahedral void and there are two tetrahedral voids available per  $S^{2-}$ . Can you give the idea about the arrangement of the lattice.  
 (ii) What is the striking difference between the Fluorite and the Anti-fluorite structures.
16. Given that  $\eta$  is the ratio of the observed to the theoretical densities of a solid. Can one give the idea about the value of  $\eta$  for the following.  
 (i) Schottky defects are present in the solid. Find fraction of the missing units.  
 (ii) Interstitial defects are present in the solid.  
 (iii) Frenkel defects are present.
17. Calculate the concentration of cation vacancies if NaCl is doped with  $10^{-3}$  mole % of  $SrCl_2$ .
18. The edge length of the unit cube of diamond is 356.7 pm and this cube contains 8 carbon atoms. Calculate:  
 (a) the distance  $d_{C-C}$  between carbon atoms, assuming them to be spheres in contact;  
 (b) the fraction of the total volume that is occupied by carbon atoms.

## EXERCISE # 3

### PART - I : IIT-JEE PROBLEMS (PREVIOUS YEARS)

\* Marked Questions are having more than one correct option.

1. In the figures given below show the location of atoms in three crystallographic planes in a fcc lattice. Draw the unit cell of the corresponding structure and identify these planes in your diagram. [JEE-2000, 3/100]

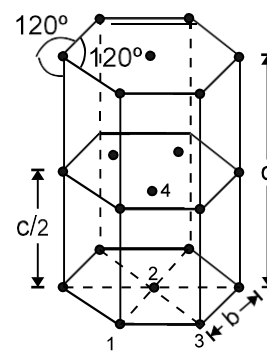


2. In a solid 'AB' having the NaCl structure, 'A' atoms occupy the corners of the cubic unit cell. If all the face centered atoms along one of the axes are removed, then the resultant stoichiometry of the solid is : [JEE-2001, 1/35]  
 (A)  $AB_2$  (B)  $A_2B$  (C)  $A_4B_3$  (D)  $A_3B_4$
3. A substance  $A_xB_y$  crystallizes in a face centered cubic lattice in which atoms 'A' occupy each corner of the cube and atoms 'B' occupy the centers of each face of the cube. Identify the correct composition of the substance  $A_xB_y$ . [JEE-2002, 3/90]  
 (A)  $AB_3$  (B)  $A_4B_3$   
 (C)  $A_3B$  (D) composition cannot be specified
4. Marbles of diameter 10 mm each are to be arranged on a flat surface so that their centers lie within the area enclosed by four lines of length each 40 mm. Sketch the arrangement that will give the maximum number of marbles per unit area, that can be enclosed in this manner and deduce the expression to calculate it. [JEE-2003, 2/60]
5. A binary salt AB (formula weight =  $6.023 Y$  amu, where  $Y$  is an arbitrary number) has rock salt structure with 1 : 1 ratio of A to B. The shortest A-B distance in the unit cell is  $Y^{1/3}$  nm. [JEE-2004, 4/60]  
 (a) Calculate the density of the salt in  $kg\ m^{-3}$ .  
 (b) Given that the measured density of the salt is  $20\ kg\ m^{-3}$ , specify the type of point defect present in the crystal.
6. In which of the following compounds the cations are present in alternate tetrahedral voids: [JEE-2005, 3/84]  
 (A) NaCl (B) ZnS (C)  $CaF_2$  (D)  $Na_2O$
7. In a FCC lattice of a metal edge length is 400 pm. Find the maximum diameter of an atom which can be accommodated in an interstitial gap in this lattice without causing any distortion. [JEE-2005, 2/60]
8. For a unit cell edge length =  $5\text{\AA}$ , the element is of atomic mass 75, has density of  $2\text{gm/cc}$ . Calculate atomic radius of the element. [JEE-2006, 6/184]
9. Match the crystal system/unit cells mentioned in **Column I** with their characteristic features mentioned in **Column II**. [JEE-2007, 6/162]

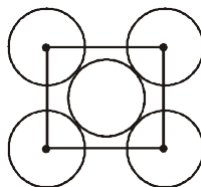
| Column I                                 | Column II                                                                   |
|------------------------------------------|-----------------------------------------------------------------------------|
| (A) simple cubic and face-centered cubic | (p) have these cell parameters<br>$a = b = c$ and $\alpha = \beta = \gamma$ |
| (B) cubic and rhombohedral               | (q) are two crystal systems                                                 |
| (C) cubic and tetragonal                 | (r) have only two crystallographic angles of $90^\circ$                     |
| (D) hexagonal and monoclinic             | (s) belong to same crystal system                                           |

## Comprehension :

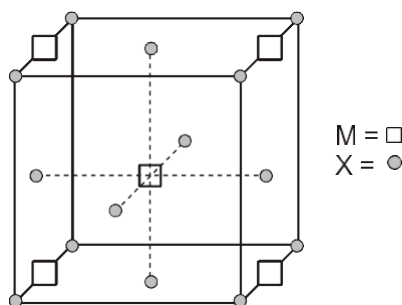
In hexagonal systems of crystals, a frequently encountered arrangement of atoms is described as a hexagonal prism. Here, the top and bottom of the cell are regular hexagons and three atoms are sandwiched in between them. A space-filling model of this structure, called hexagonal close-packed (HCP), is constituted of a sphere on a flat surface surrounded in the same plane by six identical spheres as closely as possible. These spheres are then placed over the first layer so that they touch each other and represent the second layer. Each one of these three spheres touches three spheres of the bottom layer. Finally, the second layer is covered with third layer that is identical to the bottom layer in relative position. Assume radius of every sphere to be 'r'.



10. The number of atoms in the HCP unit cell is [JEE-2008, 4/81]  
 (A) 4 (B) 6 (C) 12 (D) 17
11. The volume of this HCP unit cell is [JEE-2008, 4/81]  
 (A)  $24\sqrt{2} r^3$  (B)  $16\sqrt{2} r^3$  (C)  $12\sqrt{2} r^3$  (D)  $\frac{64}{3\sqrt{3}} r^3$
12. The empty space in this HCP unit cell is [JEE-2008, 4/81]  
 (A) 74% (B) 47.6% (C) 32% (D) 26%
13. \* The correct statement(s) regarding defects in solids is(are) : [JEE-2009, 4/80]  
 (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-center.  
 (D) Schottky defects have no effect on the physical properties of solids.
14. The packing efficiency of the two dimensional square unit cell shown below is : [JEE-2010, 5/79]



- (A) 39.27% (B) 68.02% (C) 74.05% (D) 78.54%
15. The number of hexagonal faces that are present in a truncated octahedron is. [JEE-2011s, 4/80]
16. A compound  $M_pX_q$  has cubic close packing (ccp) arrangement of X. Its unit cell structure is shown below. The empirical formula of the compound is- [JEE-2012, 5/210]



- (A)  $MX$  (B)  $MX_2$  (C)  $M_2X$  (D)  $M_5X_{14}$

## PART - II : AIEEE PROBLEMS (PREVIOUS YEARS)

1. Na and Mg crystallize in BCC and FCC type crystals respectively, then the number of atoms of Na and Mg present in the unit cell of their respective crystal is [AIEEE-2002]  
 (1) 4 and 2                      (2) 9 and 14                      (3) 14 and 9                      (4) 2 and 4
2. How many unit cells are present in a cube-shaped ideal crystal of NaCl of mass 1.00g? [AIEEE-2003]  
 [Atomic masses : Na = 23, Cl = 35.5]  
 (1)  $2.57 \times 10^{21}$                       (2)  $5.14 \times 10^{21}$                       (3)  $1.28 \times 10^{21}$                       (4)  $1.71 \times 10^{21}$
3. What type of crystal defect is indicated in the diagram below? [AIEEE-2004]  
 $\text{Na}^+ \text{Cl}^- \text{Na}^+ \text{Cl}^- \text{Na}^+ \text{Cl}^-$   
 $\text{Cl}^- \square \text{Cl}^- \text{Na}^+ \square \text{Na}^+$   
 $\text{Na}^+ \text{Cl}^- \square \text{Cl}^- \text{Na}^+ \text{Cl}^-$   
 $\text{Cl}^- \text{Na}^+ \text{Cl}^- \text{Na}^+ \square \text{Na}^+$   
 (1) Frenkel defect                      (2) Schottky defect  
 (3) interstitial defect                      (4) Frenkel and Schottky defects
4. An ionic compound has a unit cell consisting of A ions at the corners of a cube and B ions on the centers of the faces of the cube. The empirical formula for this compound would be [AIEEE-2005]  
 (1) AB                      (2)  $\text{A}_2\text{B}$                       (3)  $\text{AB}_3$                       (4)  $\text{A}_3\text{B}$
5. Total volume of atoms present in a face-center cubic unit cell of a metals (r is atomic radius) [AIEEE-2006]  
 (1)  $\frac{20}{3} \pi r^3$                       (2)  $\frac{24}{3} \pi r^3$                       (3)  $\frac{12}{3} \pi r^3$                       (4)  $\frac{16}{3} \pi r^3$
6. In a compound, atoms of element Y form ccp lattice and those of element X occupy  $\frac{2}{3}$ rd of tetrahedral voids. The formula of the compound will be [AIEEE - 2008, 3/105]  
 (1)  $\text{X}_2\text{Y}_3$                       (2)  $\text{X}_2\text{Y}$                       (3)  $\text{X}_3\text{Y}_4$                       (4)  $\text{X}_4\text{Y}_3$
7. Copper crystallises in fcc with a unit cell length of 361 pm. What is the radius of copper atom ? [AIEEE - 2009, 8/144]  
 (1) 127 pm                      (2) 157 pm                      (3) 181 pm                      (4) 108 pm
8. The edge length of a face centred cubic cell of an ionic substance is 508 pm. If the radius of the cation is 110 pm, the radius of the anion is : [AIEEE - 2010, 4/144]  
 (1) 288 pm                      (2) 398 pm                      (3) 618 pm                      (4) 144 pm
9. Percentages of free space in cubic close packed structure and in body centered packed structure are respectively. [AIEEE - 2010, 4/144]  
 (1) 30% and 26%                      (2) 26% and 32%                      (3) 32% and 48%                      (4) 48% and 26%
10. In a face centred cubic lattice, atom A occupies the corner position and atom B occupies the face centre positions. If one atom of B is missing from one of the face centred points, the formula of the compound is: [AIEEE - 2011]  
 (1)  $\text{A}_2\text{B}$                       (2)  $\text{AB}_2$                       (3)  $\text{A}_2\text{B}_3$                       (4)  $\text{A}_2\text{B}_5$
11. Lithium forms body centred cubic structure. The length of the side of its unit cell is 351 pm. Atomic radius of the lithium will be : [AIEEE - 2012]  
 (1) 75 pm                      (2) 300 pm                      (3) 240 pm                      (4) 152 pm

## EXERCISE # 4

### NCERT QUESTIONS

1. Define the term 'amorphous'. Give a few examples of amorphous solids.
2. What makes a glass different from a solid such as quartz? Under what conditions could quartz be converted into glass?
3. Classify each of the following solids as ionic, metallic, molecular, network (covalent) or amorphous.  
(i) Tetra phosphorus decoxide ( $P_4O_{10}$ )                      (ii) Ammonium phosphate  $(NH_4)_3PO_4$   
(iii) SiC                                                                      (iv)  $I_2$   
(v)  $P_4$                                                                         (vi) Plastic  
(vii) Graphite                                                              (viii) Brass  
(ix) Rb                                                                        (x) LiBr  
(xi) Si
4. (i) What is meant by the term 'coordination number'?  
(ii) What is the coordination number of atoms :  
    (a) in a cubic close-packed structure?  
    (b) in a body-centred cubic structure?
5. How can you determine the atomic mass of an unknown metal if you know its density and the dimension of its unit cell? Explain.
6. 'Stability of a crystal is reflected in the magnitude of its melting points'. Comment. Collect melting points of solid water, ethyl alcohol, diethyl ether and methane from a data book. What can you say about the intermolecular forces between these molecules?
7. How will you distinguish between the following pairs of terms :  
(i) Hexagonal close-packing and cubic close-packing?  
(ii) Crystal lattice and unit cell?  
(iii) Tetrahedral void and octahedral void?
8. How many lattice points are there in one unit cell of each of the following lattice?  
(i) Face-centred cubic  
(ii) Face-centred tetragonal  
(iii) Body-centred
9. Explain  
(i) The basis of similarities and differences between metallic and ionic crystals.  
(ii) Ionic solids are hard and brittle.
10. Calculate the efficiency of packing in case of a metal crystal for  
(i) simple cubic  
(ii) body-centred cubic  
(iii) face-centred cubic (with the assumptions that atoms are touching each other).
11. Silver crystallises in fcc lattice. If edge length of the cell is  $4.07 \times 10^{-8}$  cm and density is  $10.5 \text{ g cm}^{-3}$ , calculate the atomic mass of silver.

12. A cubic solid is made of two elements P and Q. Atoms of Q are at the corners of the cube and P at the body-centre. What is the formula of the compound? What are the coordination numbers of P and Q?
13. Niobium crystallises in body-centred cubic structure. If density is  $8.55 \text{ g cm}^{-3}$ , calculate atomic radius of niobium using its atomic mass 93 u.
14. If the radius of the octahedral void is  $r$  and radius of the atoms in closepacking is  $R$ , derive relation between  $r$  and  $R$ .
15. Copper crystallises into a fcc lattice with edge length  $3.61 \times 10^{-8} \text{ cm}$ . Show that the calculated density is in agreement with its measured value of  $8.92 \text{ g cm}^{-3}$ .
16. Analysis shows that nickel oxide has the formula  $\text{Ni}_{0.98}\text{O}_{1.00}$ . What fractions of nickel exist as  $\text{Ni}^{2+}$  and  $\text{Ni}^{3+}$  ions?
17. What is a semiconductor? Describe the two main types of semiconductors and contrast their conduction mechanism.
18. Non-stoichiometric cuprous oxide,  $\text{Cu}_2\text{O}$  can be prepared in laboratory. In this oxide, copper to oxygen ratio is slightly less than 2:1. Can you account for the fact that this substance is a p-type semiconductor?
19. Ferric oxide crystallises in a hexagonal close-packed array of oxide ions with two out of every three octahedral holes occupied by ferric ions. Derive the formula of the ferric oxide.
20. Classify each of the following as being either a p-type or a n-type semiconductor :  
(i) Ge doped with In      (ii) Si doped with B.
21. Gold (atomic radius = 0.144 nm) crystallises in a face-centred unit cell. What is the length of a side of the cell?
22. In terms of band theory, what is the difference  
(i) between a conductor and an insulator  
(ii) between a conductor and a semiconductor?
23. Explain the following terms with suitable examples :  
(i) Schottky defect      (ii) Frenkel defect  
(iii) Interstitials and      (iv) F-centres.
24. Aluminium crystallises in a cubic close-packed structure. Its metallic radius is 125 pm.  
(i) What is the length of the side of the unit cell?  
(ii) How many unit cells are there in  $1.00 \text{ cm}^3$  of aluminium?
25. If NaCl is doped with  $10^{-3} \text{ mol \%}$  of  $\text{SrCl}_2$ , what is the concentration of cation vacancies?
26. Explain the following with suitable examples :  
(i) Ferromagnetism      (ii) Paramagnetism  
(iii) Ferrimagnetism      (iv) Antiferromagnetism  
(v) 12-16 and 13-15 group compounds.

# ANSWERS

## Exercise # 1

### PART - I

|      |     |       |     |       |     |        |       |       |     |        |       |        |      |
|------|-----|-------|-----|-------|-----|--------|-------|-------|-----|--------|-------|--------|------|
| A-1. | (A) | A-2.  | (A) | A-3.  | (C) | A-4.   | (C)   | B-1.  | (A) | B-2.   | (A)   | B-3.   | (B)  |
| B-4. | (C) | C-1.  | (A) | C-2.  | (A) | C-3.   | (C)   | C-4.  | (D) | C-5.   | (B)   | C-6.   | (D)  |
| C-7. | (B) | D-1.  | (B) | D-2.  | (C) | D-3.   | (A)   | D-4.  | (D) | D-5.   | (C)   | D-6.   | (C)  |
| D-7. | (C) | D-8.  | (C) | D-9.  | (A) | D-10.* | (B*C) | D-11. | (C) | D-12.  | (A)   | E-1.   | (C)  |
| E-2. | (A) | E-3.  | (D) | E-4.  | (A) | E-5.   | (C)   | E-6.  | (A) | E-7.   | (B)   | F-1.   | (C)  |
| F-2. | (C) | F-3.  | (A) | F-4.  | (A) | F-5.   | (C)   | F-6.  | (C) | F-7.   | (D)   | F-8.   | (C)  |
| F-9. | (B) | F-10. | (A) | F-11. | (D) | F-12.  | (A)   | F-13. | (B) | F-14.* | (ABD) | F-15.* | (AB) |
| G-1. | (B) | G-2.  | (B) | G-3.  | (C) | G-4.   | (B)   | G-5.  | (B) | G-6.   | (B)   | G-7.   | (B)  |
| G-8. | (D) | G-9.  | (A) |       |     |        |       |       |     |        |       |        |      |

### PART - II

|     |                             |     |                  |     |                               |     |                                  |     |     |     |     |     |     |
|-----|-----------------------------|-----|------------------|-----|-------------------------------|-----|----------------------------------|-----|-----|-----|-----|-----|-----|
| 1.  | (B)                         | 2.  | (B)              | 3.  | (C)                           | 4.  | (D)                              | 5.  | (D) | 6.  | (A) | 7.  | (C) |
| 8.  | (B)                         | 9.  | (A)              | 10. | (C)                           | 11. | (A) p, s (B) p, q (C) q (D) q, r |     |     |     |     |     |     |
| 12. | (A) p (B) q, s (C) r        |     |                  | 13. | (A) r, s (B) p, q, r, s (C) q |     |                                  | 14. | (C) | 15. | (A) |     |     |
| 16. | (B)                         | 17. | (A)              | 18. | F                             | 19. | T                                | 20. | T   | 21. | T   |     |     |
| 22. | T                           | 23. | T                | 24. | T                             | 25. | T                                | 26. | F   | 27. | F   | 28. | F   |
| 29. | $\sqrt{3} a = 4r$           | 30. | cubic close, FCC | 31. | hexagonal close, HP           |     |                                  |     |     |     |     |     |     |
| 32. | least or minimum            | 33. | 12               | 34. | 0.732                         | 35. | $\frac{\sqrt{3}a}{2}$            |     |     |     |     |     |     |
| 36. | decreases, remains constant | 37. | 23               | 38. | simple cubic                  |     |                                  |     |     |     |     |     |     |
| 39. | $\text{ZnAl}_2\text{O}_4$   |     |                  |     |                               |     |                                  |     |     |     |     |     |     |

## Exercise # 2

### PART - I

|     |      |     |       |     |       |     |       |     |       |     |       |     |      |
|-----|------|-----|-------|-----|-------|-----|-------|-----|-------|-----|-------|-----|------|
| 1.  | (B)  | 2.  | (B)   | 3.  | (A)   | 4.  | (A)   | 5.  | (B)   | 6.  | (C)   | 7.  | (A)  |
| 8.  | (D)  | 9.  | (A)   | 10. | (A)   | 11. | (A)   | 12. | (A)   | 13. | (C)   | 14. | (C)  |
| 15. | (C)  | 16. | (B)   | 17. | (B)   | 18. | (A)   | 19. | (A)   | 20. | (D)   | 21. | (B)  |
| 22. | (A)  | 23. | (B)   | 24. | (C)   | 25. | (B)   | 26. | (D)   | 27. | (A)   | 28. | (D)  |
| 29. | (B)  | 30. | (A)   | 31. | (C)   | 32. | (B)   | 33. | (C)   | 34. | (A)   | 35. | (AC) |
| 36. | (AC) | 37. | (ACD) | 38. | (ABC) | 39. | (ABD) | 40. | (ABC) | 41. | (ABC) |     |      |

### PART - II

- $Z = \rho N_0 a^3 / M = 10.7 \times 10^3 \times 6.023 \times 10^{23} \times (4.06 \times 10^{-10})^3 / (108 \times 10^{-3}) = 4$   
Thus there are 4 atoms per unit cell. Hence it is FCC.
- $\text{XY}_3$ ,  $4.38 \text{ g/cm}^3$
- (a)  $3.52 \text{ \AA}$ , (b)  $1.24 \text{ \AA}$
- (i)  $r^2 \sqrt{3}$ ; (ii)  $2r \sqrt{2/3}$ ; (iii) Yes, of course
- (i) b, f, g are identical; c, e are identical. (ii)  $d_a < [d_b = d_f = d_g] < [d_c = d_e] < d_d$

6. (a)  $XY_3$  (b) (i)  $X_7Y_{24}$  (ii)  $XY_4$  (iii)  $X_7Y_{24}Z$  7. (i)  $2r, 2r, 2\sqrt{3}r$ ; (ii) Square, side =  $2r$ .
8. No 9.  $A_2B$  10.  $Al_2O_3$  11. 6
12. At the center of the cube, Volume =  $1000(\sqrt{3} + 1)^3 \text{ \AA}^3$  13.  $ZnAl_2O_4$  14.  $4(r + 2R)$
15. (i)  $Zn^{2+}$  ions occupy alternate Tetrahedral holes; (ii) Anti-Fluorite: Anions in FCC and Cations in Tetrahedral holes, Fluorite: Cations in FCC and Anions in Tetrahedral holes
16. (i)  $\eta < 1$ , fraction =  $(1 - \eta)$ ; (ii)  $\eta > 1$ ; (iii)  $\eta = 1$ . 17.  $6.02 \times 10^{18}$
18. (a) 154.4 pm (b) 0.34

### Exercise # 3

#### PART - I

2. (D) 3. (A) 4. 25, 1.804 marbles/cm<sup>2</sup>
5. (a)  $5 \text{ kg m}^{-3}$  (b) Cancelled (Full marks given in part a)
6. (B) 7. 117.08 pm 8. 216.5 pm.
9. (A) p, s; (B) p, q; (C) q; (D) q, r 10. (B) 11. (A) 12. (D) 13.\* (BC)
14. (D) 15. 8 16. (B)

#### PART - II

1. (4) 2. (1) 3. (2) 4. (3) 5. (4) 6. (4) 7. (1)
8. (4) 9. (2) 10. (4) 11. (4)

### Exercise # 4

3. Ionic  $\rightarrow$  (ii) Ammonium phosphate  $(NH_4)_3PO_4$ , (x) LiBr  
 Metallic  $\rightarrow$  (viii) Brass, (ix) Rb  
 Molecular  $\rightarrow$  (i) Tetraphosphorus decoxide  $(P_4O_{10})$ , (iv)  $I_2$ , (v)  $P_4$   
 Covalent (network)  $\rightarrow$  (iii) SiC, (vii) Graphite, (xi) Si  
 Amorphous  $\rightarrow$  (vi) Plastic
4. (i) The number of nearest neighbours of any constituent particle present in the crystal lattice is called its coordination number.  
 (ii) The coordination number of atoms  
 (a) in a cubic close-packed structure is 12, and  
 (b) in a body-centred cubic structure is 8
8. (i) There are 14 (8 from the corners + 6 from the faces) lattice points in face-centred cubic.  
 (ii) There are 14 (8 from the corners + 6 from the faces) lattice points in face-centred tetragonal.  
 (iii) There are 9 (1 from the centre + 8 from the corners) lattice points in body-centred cubic.
11. 107.13 u 13. 14.32 nm 16. 0.041 21. 0.407 nm
24. (i) 354 pm (approximately) (ii)  $2.27 \times 10^{22}$  25.  $6.022 \times 10^{18} \text{ mol}^{-1}$