

## Solved Examples

### JEE Main/Boards

**Example 1:** Both diamond and rhombic (solid) sulphur are covalent solids, however, the latter has very low m.pt. in comparison to diamond. Explain.

**Sol:** Value of Boiling point and melting point depends on intermolecular force of attraction. By taking into consideration the forces that help the two structure (diamond and sulphur) to hold together, answer the question.

Diamond has three dimensional covalent network and strong intermolecular forces whereas rhombic sulphur has one dimensional covalent network with puckered eight membered ring held together by weak van der Waals' forces.

**Example 2:** Calculate the number (n) of atoms contained within (a) simple cubic cell (b) a body centred cubic cell (c) a face centred cubic cell.

**Sol:** (a) The simple cubic unit cell has 8 atoms at eight corners. Each atom is shared by 8 unit cells.

$$\therefore n = 8 \times \frac{1}{8} = 1$$

(b) The body centred cubic cell consists of 8 atoms at the corners and one atom at centre.

$$\therefore n = \left( 8 \times \frac{1}{8} \right) + 1 = 2$$

(c) The face centred cubic unit cell consists of 8 atoms at the eight corners and one atom at each of the six faces. This atom at the face is shared by two unit cells.

$$\therefore n = 8 \times \frac{1}{8} + \left( 6 \times \frac{1}{2} \right) = 4$$

**Example 3:** An element having atomic mass 60 has face centred cubic unit cells. The edge length of the unit cell is 400 pm. Find out density of the element.

**Sol:** From the edge length determine the volume of unit cell as, Volume =  $a^3$

Density can be determined using the following expression that relates density with edge length.

$$\rho = \frac{4 \times M_w}{N_A \times a^3 \times 10^{-30}}$$

Edge length of unit cell = 400 pm

$$= 400 \times 10^{-12} \text{ m}$$

$$(1 \text{ pm} = 10^{-12} \text{ m})$$

$$= 400 \times 10^{-10} \text{ cm}$$

Volume of unit cell

$$= (400 \times 10^{-10} \text{ cm})^3$$

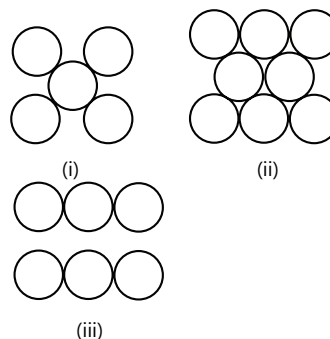
$$= 64 \times 10^{-24} \text{ cm}^3$$

Number of atoms (n) in the fcc unit cell = 4

$$\therefore \text{Density} = \frac{4 \times 60}{6.023 \times 10^{23} \times 64 \times 10^{-24}}$$

$$= 6.23 \text{ g cm}^{-3}$$

**Example 4:** The figures given below show the location of atoms in three crystallographic planes in a fcc lattice. Draw the unit cell for the corresponding structure and identify these planes in your diagram.



**Sol:** (i) Face plane,

(ii) Face diagonal plane and

(iii) Diagonal plane

**Example 5:** Ferric oxide crystallizes in a hexagonal closed packed array of oxide ions, with two out of every three octahedral holes occupied by ferric ions. Derive the formula of the ferric oxide.

**Sol:** Hexagonal close packing has an array of oxide ions, where two out of three octahedral holes occupied by  $\text{Fe}^{3+}$  ions has one octahedral void or holes corresponding to each atom constituting the close packing. In iron oxide only 2/3 of octahedral holes are occupied by  $\text{Fe}^{3+}$  ions. It means corresponding to each oxide ion, there are 2/3  $\text{Fe}^{3+}$  ions. Thus, molecular formula of iron oxide is  $\text{Fe}_2\text{O}_3$ .

**Example 6:** The structure of CsCl is different from NaCl, though both have the similar formula. Explain.

**Sol:** CsCl has radius ratio  $\geq 0.732$  and shows cubic arrangement, whereas radius of NaCl is  $< 0.732$  and has octahedral arrangement.

**Example 7:** Calculate the wavelength of X-rays, which produces a different angle  $2\theta$  equal to  $16.80^\circ$  for a crystal. Assume first order diffraction with inter particle distance in crystal of 0.2 nm.

**Sol:** using Bragg's equation,  $n\lambda = 2d\sin\theta$

Calculate the Wavelength.

Given,  $n = 1$ ,  $d = 0.2 \times 10^{-9}$  m,

$$\theta = \frac{16.80}{2} = 8.40^\circ$$

$$\text{Thus, } \lambda = \frac{2 \times 0.2 \times 10^{-9} \sin 8.4}{1} = 5.84 \times 10^{-11} \text{ m}$$

**Example 8:** Explain, why solids with F-centres are paramagnetic?

**Sol:** Solids containing F-centres are paramagnetic because the electrons occupying the holes are unpaired.

**Example 9:** A fcc lattice cube is formed by atoms A and B. If atom A is present at the corner of the cube and the atom B at the faces of the cube. Find out the formula of the compound.

**Sol:** Contribution of atom 'A' at eight corners of the cube

$$= \frac{1}{8} \times 8 = 1 \text{ atom}$$

Contribution of atom at each face =  $\frac{1}{2}$  atom

$\therefore$  The atom 'B' at six faces of the cube

$$= \frac{1}{2} \times 6 = 3 \text{ atom}$$

$\therefore$  Formula of the compound = **AB<sub>3</sub>**

**Example 10:** A metallic element crystallizes into a lattice containing a sequence of layers of ABABAB ..... Any packing of spheres leaves out voids in the lattice. What percentage by volume of this lattice is empty space?

$$\begin{aligned} \text{Sol: Packing fraction in hcp} &= \frac{6 \times \frac{4}{3} \pi r^3}{\text{Volume}} \\ &= \frac{6 \times 4\pi r^3}{3 \times \text{Area} \times \text{Height}} \end{aligned}$$

Area (of base) of unit cell in hcp

$$= 6\sqrt{3}r^2 \text{ (Follow text)}$$

Height of unit cell in hcp

$$= 4r \times \sqrt{\frac{2}{3}} \text{ (follow text)}$$

$$\begin{aligned} \therefore \text{Packing fraction} &= \frac{6 \times 4\pi r^3}{3 \times 6\sqrt{3}r^2 \times 4r \times \sqrt{\frac{2}{3}}} \\ &= \frac{\pi}{3\sqrt{2}} = 0.74 \text{ or } 74\% \end{aligned}$$

Thus, empty space in hcp =  $1 - 0.74 = 0.26$  or 26%

## JEE Advanced/Boards

**Example 1:** Metallic gold crystallizes in the face-centred cubic lattice. The length of the cubic unit cell is  $a = 4.070 \text{ \AA}$ .

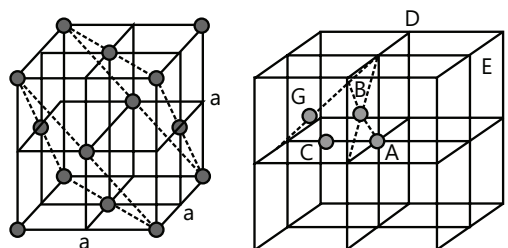
- What is the closest distance between gold atoms?
- How many 'nearest neighbours' does each gold atom have at the distance calculated in (a)?
- What is the density of gold?
- Prove that the packing factor for gold, the fraction of the total volume occupied by the atoms themselves, is 0.74.

**Sol:** (a) In fcc,  $a = 2\sqrt{2}r$

$$\therefore 2r = \frac{a}{\sqrt{2}}$$

$2r$  is closest distance between two atom.

$$\therefore 2r = \frac{4.070}{1.414} = 2.878 \text{ \AA}$$



(b) The problem is to find how many face centers are equidistant from a corner atom. Point A in figure may be taken as the reference corner atom. In that same figure, B is one of the face-center points at the nearest distance to A. In plane ABD in the figure, there are three other points equally close to A: the centers of the squares in the upper right, lower left, and lower right quadrants of the plane, measured around A. Plane ACE,

parallel to the plane of the paper, also has points in the centers of each of the squares in the four quadrants around A. Also, plane ACF, perpendicular to the plane of the paper, has points in the centers of each of the squares in the four quadrants around A. Thus there are 12 nearest neighbors in all, the number expected for a close-packed structure.

The same result would have been obtained by counting the nearest neighbours around B, a face-centered point.

(c) In fcc,  $n = 4$ ,  $M = 197 \text{ g mol}^{-1}$

$$a = 4.070 \text{ \AA} = 4.070 \times 10^{-10} \text{ cm}$$

$$\text{density} = \frac{n \times M}{N_A \cdot a^3} = \frac{4 \times 197}{6.022 \times 10^{23} \times (4.07 \times 10^{-10})^3}$$

$$= 19.4 \text{ g cm}^{-3}$$

(d) Since atoms at closest distance are in contact in a close-packed structure, the closest distance between centres calculated in (a),  $\frac{a}{\sqrt{2}}$ , must equal the sum of the radii of the two spherical atoms,  $2r$ . Thus,  $r = a/2^{3/2}$ . From (c), there are 4 gold atoms per unit cell.

$$\text{Then, Volume of 4 gold atoms} = 4 \left( \frac{4}{3} \pi r^3 \right)$$

$$\therefore \text{Volume of unit cell} = a^3$$

$$= (2\sqrt{2}r)^3$$

$$= 16\sqrt{2}r^3$$

$$\therefore \text{Packing fraction} = \frac{\text{volume of 4 gold atoms}}{\text{volume of unit cell}}$$

$$= \frac{\frac{16}{3} \pi r^3}{16\sqrt{2}r^3} = \frac{\pi}{3\sqrt{2}} = 0.74$$

**Example 2:** A metal crystallizes into two cubic phases, face centred cubic (FCC) and body centred cubic (BCC), whose unit cell lengths are 3.5 and 3.0 Å, respectively. Calculate the ratio of densities of FCC and BCC.

**Sol:** We know that

$$\rho = \frac{Z \times \text{Formula mass of substance}}{N_0 \times a^3}$$

Since for FCC,  $Z = 4$  and for BCC,  $Z = 2$

$$d_{\text{FCC}} = \frac{4 \times \text{Formula mass of metal}}{N_0 \times (3.5)^3}$$

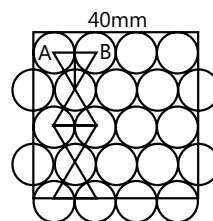
$$\text{and } d_{\text{BCC}} = \frac{2 \times \text{Formula mass of metal}}{N_0 \times (3)^3}$$

Dividing  $d_{\text{FCC}}$  and  $d_{\text{BCC}}$

$$\frac{d_{\text{FCC}}}{d_{\text{BCC}}} = \frac{4}{2} \times \frac{(3)^3}{(3.5)^3} = 2 \times 0.6297 = 1.259$$

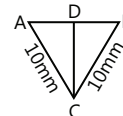
**Example 3:** You are given some marbles with a diameter of 10mm. They are to be placed such that their centres are lying in a square bond by four lines each of length 40 mm. What will be the arrangements of marbles in a plane so that maximum number of marbles can be placed inside the area? Sketch the diagram and derive expression for the number of molecules per unit area.

**Sol:** Area of square having spherical marbles in it



$$= 40 \times 10^{-1} \times 40 \times 10^{-1} \text{ cm}^2$$

$$= 16 \text{ cm}^2$$



$$CD = 10 \sin 60^\circ = 10 \frac{\sqrt{3}}{2} = 5\sqrt{3}$$

The maximum number of spheres of 10 mm diameter in hcp packing can be seen in figure.

Total length converted by spheres

$$= 5 + 4 \times CD = 5 + 4 \times 10 \sin 60^\circ$$

$$= 5 + 4 \times 5\sqrt{3} = 40 \text{ mm} = 4 \text{ cm}$$

Maximum number of spheres (s)

$$= 14 + 8$$

$$\text{(Full) (half)}$$

$$= 14 + 4 = 18$$

$$\therefore \text{Number of spheres per cm}^2 = \frac{18}{16} = \mathbf{1.125}$$

**Example 4:** Using the given data find out the type of cubic lattice to which the crystal belong:

	Fe	V	Pd	Al
a in pm	286	301	388	405
$\rho$ in $\text{g cm}^{-3}$	7.86	5.96	12.16	2.70
At. mass in $\text{g mol}^{-1}$	55.85	50.94	106.4	26.98

**Sol:** We know,  $\rho = \frac{n \times \text{At. mass}}{N_0 \times a^3}$

or  $n = \frac{\rho \times N_0 \times a^3}{\text{At. mass}}$

**For Fe:**

$$n = \frac{7.86 \times 6.023 \times 10^{23} \times (286 \times 10^{-10})^3}{55.85} = 2$$

(i.e., cubic lattice of Fe is body centred)

**For V:**

$$n = \frac{5.96 \times 6.023 \times 10^{23} \times (301 \times 10^{-10})^3}{50.94} = 2$$

(i.e., cubic lattice of V is body centred)

**For Pd:**

$$n = \frac{12.16 \times 6.023 \times 10^{23} \times (388 \times 10^{-10})^3}{106.4} = 4$$

(i.e., cubic lattice of Pd is face centred)

**For Al:**

$$n = \frac{2.70 \times 6.023 \times 10^{23} \times (405 \times 10^{-10})^3}{26.98} = 4$$

(i.e., cubic lattice of Al is face centred)

**Example 5:** The density of a particular crystal of LiF is 2.65 g/cc. X-ray analysis shows that Li<sup>+</sup> and F<sup>-</sup> ions are arranged in a cubic array at a spacing of 2.01 Å. From these data calculate the apparent Avogadro constant.

[Li = 6.939, F = 18.998 (1 Å = 10<sup>-8</sup> cm)]

**Sol:** In this problem, we have to calculate Avogadro constant, i.e., the number of LiF molecules present in 1 mole of LiF weighs 25.937 g

(LiF = 6.939 + 18.998),

$$\begin{aligned} \text{Volume of 1 mole} &= \frac{\text{wt. of 1 mole}}{\text{wt. per cc (density)}} \\ &= \frac{25.937}{2.65} = 9.78 \text{ cc.} \end{aligned}$$

Since this volume is supposed to be a cube, the length of each edge of the cube

$$= \sqrt[3]{9.78} = 2.138 \text{ cm.}$$

Number of ions present in one edge

$$= \frac{2.138}{2.01 \times 10^{-8}} = 1.063 \times 10^8$$

Number of ions (Li<sup>+</sup> + F<sup>-</sup>) present in cube

$$= (1.063 \times 10^8)^3 = 1.201 \times 10^{24}$$

Number of LiF molecules per mole

(i.e., Avogadro constant)

$$= \frac{1.201 \times 10^{24}}{2} = 6.01 \times 10^{23}$$

**Example 6:** Calculate the glancing angle on the cube (100) of a rock salt (a = 2.814 Å) corresponding to second order diffraction maximum for X-rays of wavelength 0.710 Å.

**Sol:** First determine the distance between lattice plane by using the following expression,  $d_{hkl} = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$

And then  $\theta$  angle can be calculated using Bragg's equation

$$2d \sin \theta = n\lambda \quad \dots(i)$$

The distance between consecutive lattice planes is defined by Miller indices (h, k, l) in a cubic lattice by the relation

$$d_{hkl} = \frac{a}{\sqrt{h^2 + k^2 + l^2}} = 2.814 \text{ Å, } h=1, k=0, l=0$$

$$\therefore d_{100} = \frac{2.814 \text{ Å}}{\sqrt{1^2 + 0^2 + 0^2}} = 2.814 \text{ Å} = 2.814 \times 10^{-8} \text{ cm}$$

From equation (i)

$$2 \times 2.814 \times 10^{-8} \sin \theta = 2 \times 0.710 \times 10^{-8}$$

$$\sin \theta = \frac{2 \times 0.710 \times 10^{-8}}{2 \times 2.814 \times 10^{-8}} = 0.2533$$

$$\sin \theta = 0.2533$$

$$\therefore \theta = \sin^{-1}(0.2533)$$

$$\text{or } \theta = 14^\circ 36' 40''$$

**Example 7:** The edge length of unit cell of a metal having molecular weight 75 g mol<sup>-1</sup> is 5 Å which crystallizes in body centred cubic lattice. If density is 2 g cm<sup>-3</sup>, calculate radius of metal atom.

**Sol:** Density =  $\frac{n \times \text{Mol. wt.}}{V \times N_A}$

$$2 = \frac{2 \times 75}{a^3 \times 6.023 \times 10^{23}}$$

(n = 2 for bcc)

$$\therefore a = 5 \times 10^{-8} \text{ cm}^3$$

$$\therefore r = \frac{\sqrt{3}}{4} \times a = \frac{\sqrt{3}}{4} \times 5 \times 10^{-8}$$

$$= 2.16 \times 10^{-8} \text{ cm} = 216 \text{ pm}$$

**Example 8:** A solid compound contains X, Y and Z atoms in a cubic lattice with X atoms occupying the corners, Y atoms in the body centred position and Z atom at the centre of the face of the unit cell. What is the empirical formula of the compound?

- (A)  $XY_2Z_3$                       (B)  $XYZ_3$   
 (C)  $X_2Y_2Z_3$                       (D)  $X_8YZ_6$                       (E)  $XYZ$

**Sol: (B)** Number of atoms of X in a unit cell =  $\frac{1}{8} \times 8 = 1$

Number of atoms of Y in a unit cell = 1

Number of atoms of Z in a unit cell =  $\frac{1}{2} \times 6 = 3$

Empirical formula of the compound =  $XYZ_3$

**Example 9:** When an electron in an excited state of Mo atom falls from L to K-shell, an X-ray is emitted. These X-rays are diffracted at angle of  $7.75^\circ$  by planes with a separation of  $2.64 \text{ \AA}$ . What is the difference in energy between K-shell and L-shell in Mo, assuming a first order diffraction? ( $\sin 7.75^\circ = 0.1349$ )

**Sol:** Using Bragg's equation first determine the wavelength and then energy can be calculated as

$$E = \frac{hc}{\lambda}$$

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

$$1 \times \lambda = 2 \times 2.64 \sin 7.75^\circ$$

$$= 2 \times 2.64 \times 0.1349$$

$$\lambda = 0.712 \text{ \AA}$$

Energy difference between K and L-shell of Mo

$$= \frac{hc}{\lambda} = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{0.712 \times 10^{-10}} = 2.791 \times 10^{-15} \text{ J}$$

**Example 10:** The density of crystalline sodium chloride is  $2.165 \text{ g cm}^{-3}$ . What is the edge length of the unit cell? What would be the dimensions of cube containing one mole of NaCl?

**Sol:** We know that,  $\rho = \frac{N}{a^3} \left( \frac{M}{N_A} \right)$

Where,  $\rho = \text{density} = 2.165 \text{ g cm}^{-3}$

M = molar mass = 58.5

$N_A = \text{Avogadro's number} = 6.023 \times 10^{23}$

N = number of formula unit

per unit cell = 4 (for bcc)

$$a^3 = \frac{N}{\rho} \left( \frac{M}{N_A} \right) = \frac{4}{2.165} \left[ \frac{58.5}{6.023 \times 10^{23}} \right] = 1.794 \times 10^{-22}$$

$$a = 5.64 \times 10^{-8} \text{ cm}$$

$$\text{Molar volume} = \frac{\text{Molar mass}}{\text{Density}} = \frac{58.8}{2.165}$$

$$\text{Edge length (a)} = \left[ \frac{58.8}{2.165} \right]^{1/3} = 3 \text{ cm}$$

**Example 11:** In a solid AB having the NaCl structure, A atoms occupy the corners of the cubic unit cell. If all the face centred atoms along one of the axis are removed. what would be the resultant stoichiometry of solid?

**Sol:** AB has NaCl structure, i.e., 8 corner and 6 face centred atoms. If we remove face centred atoms of one axis, two face centred atoms are removed. Thus, A is at 8 corners and B is at four faces.

$$\therefore \text{Contribution of A} = \frac{8}{8} = 1$$

$$\text{Contribution of B} = \frac{4}{2} = 2$$

$$\therefore \text{Stoichiometry of resultant solid is } AB_2.$$

## JEE Main/Boards

### Exercise 1

**Q.1** Explain each of the following with a suitable example:

- (i) Paramagnetism.
- (ii) Frenkel defect in crystals.

**Q.2** State the difference between Schottky and Frenkel defects. Which of the two changes the density of the solid?

**Q.3** (a) What is meant by anisotropy?

(b) Give a sketch of arrangement of particles in a solid which would show anisotropy.

**Q.4** (a) Explain with the help of figure square close-packing and hexagonal close-packing of particles in a solid in two dimensions.

(b) What is the coordination number of a particle in the two packings?

**Q.5** Some crystal defects are shown in the figures below:



Indicate the types of defect shown by (a) and (b).

**Q.6** A compound is formed by two elements M and N. The element N forms ccp and atoms of M occupy  $1/3$ rd of tetrahedral voids. What is the formula of the compound?

**Q.7** An element with molar mass  $2.7 \times 10^{-2}$  kg mol<sup>-1</sup> forms a cubic unit cell with edge length 405 pm. If its density is  $2.7 \times 10^3$  kg m<sup>-3</sup>, what is the nature of the cubic unit cell?

**Q.8** An element occurs in bcc structure with cell edge 300 pm. The density of the element is 5.2 g cm<sup>-3</sup>. How many atoms of the element does 200 g of the element contain?

**Q.9** The density of chromium metals is 7.2 g cm<sup>-3</sup>. If the unit cell has edge length of 289 pm, determine the type of unit cell. [Atomic mass of Cr = 52 u;  $N_A = 6.02 \times 10^{23}$  mol<sup>-1</sup>]

**Q.10** An element crystallizes in fcc structure. 200 g of this element has  $4.12 \times 10^{24}$  atoms. The density of A is 7.2 g cm<sup>-3</sup>. Calculate the edge length of the unit cell.

**Q.11** Lithium metal crystal has body-centred cubic structure. Its density is 0.53 g cm<sup>-3</sup> and its molecular mass is 6.94 g mol<sup>-1</sup>. Calculate the volume of a unit cell of lithium metal. [ $N_A = 6.023 \times 10^{23}$  mol<sup>-1</sup>]

**Q.12** If NaCl crystals are doped with  $2 \times 10^{-3}$  mol per cent of SrCl<sub>2</sub>, calculate the cation vacancies per mole.

**Q.13** An element exists in bcc structure with a cell edge of 288 pm. If the density of the element is 7.2 g cm<sup>-3</sup>, what is the atomic mass of the element? [ $N_A = 6.023 \times 10^{23}$  mol<sup>-1</sup>]

**Q.14** An element A crystallises in fcc structure, 208 g of this element has  $4.283 \times 10^{24}$  atoms. If edge length of the unit cell of this element is 408 pm, calculate its density.

**Q.15** Copper crystallises in face-centred cubic lattice and has a density of 8.930 g cm<sup>-3</sup> at 239 K. Calculate the radius of Copper atom. [At. mass of Cu = 63.55 u, Avogadro's constant  $N_A = 6.02 \times 10^{23}$  mol<sup>-1</sup>]

**Q.16** Metallic gold crystallises in a fcc lattice and has a density of 19.3 g cm<sup>-3</sup>. Calculate the radius of gold atom. [At. mass of gold = 197 u,  $N_A = 6.023 \times 10^{23}$  mol<sup>-1</sup>]

**Q.17** A substance forms face-centred cubic crystals. If the edge length of the unit cell is 630 pm and density of the substance is 1.984 g cm<sup>-3</sup>, calculate the molar mass of substance.

**Q.18** In a solid AB, having the NaCl structure, B atoms occupy the corners of the cubic unit cell. If all the face centred atoms along one of the axes are removed, then what is the resulting stoichiometry of the solid?

**Q.19** Lithium boron hydride crystallizes in an orthorhombic system with 4 molecules per unit cell. The unit cell dimensions are  $a = 6.8$  Å,  $b = 4.4$  Å and  $c = 7.2$  Å. If the molar mass is 21.76, calculate density of crystal.

**Q.20** The simple cubic lattice consists of eight identical spheres of radius R in contact, placed at the corners of a cube, what is the volume of the cubical box that will just enclose these eight spheres and what fraction of this volume is actually occupied by the spheres?

**Q.21** In an ionic oxide, oxide ions are arranged in hcp array and positive ion occupy two thirds of octahedral void. Suggest the simplest formula assuming metal as M.

**Q.22** A compound containing Zn, Al and S crystallises with a closed packed array of sulphide ions. Zinc ions are found in one-eighth of the tetrahedral holes and aluminium ions in one half of the octahedral holes. What is the empirical formula of the compound?

**Q.23** What is the percent by mass of titanium in rutile, a mineral that contains Ti and oxygen? If structure can be described as a closest packed array of oxide ions with titanium ions in a one-half of the octahedral holes? What is the oxidation number of titanium? (Ti = 48)

**Q.24** Calculate packing efficiency in ccp structure. How does it differ from packing efficiency in hcp structure?

**Q.25** A strong current of trivalent gaseous boron passed through a germanium crystal decreases the density of the crystal due to part replacement of germanium by boron and due to interstitial vacancies created by missing Ge atoms. In one such experiment, one gram of germanium is taken and the boron atoms are found to be 150 ppm by weight, when the density of the Ge crystal decreases by 4%. Calculate the percentage of missing vacancies due to germanium, which are filled up by boron atoms. [Atomic wt. Ge = 72.6, B = 11]

**Q.26** What is a semiconductor? Describe two main types of semiconductors and explain mechanism for their conduction.

**Q.27** (a) The electrical conductivity of a metal decreases with rise in temperature while that of a semiconductor increases. Explain.

(b) The ions of NaF and MgO have the same number of electrons and internuclear distances are about the same [235 pm and 215 pm]. Why are then the melting points of NaF and MgO so different [992°C and 2642°C]?

(c) Why does zinc oxide exhibit enhanced electrical conductivity on heating?

**Q.28** Bring out with the help of a sketch the difference between metals insulators and semiconductors in terms of energy gap between valence band and conduction band.

**Q.29** Explain with the help of a figure, how an electron (i) moving in an orbital and (ii) spinning in an atom give magnetic properties.

**Q.30** How can you show with the help of a diagram that number of octahedral voids is equal to the number of atoms in cubic close packed structure?

## Exercise 2

### Single Correct Choice Type

**Q.1** A solid has a structure in which W atoms are located at the corners of a cubic lattice, O atom at the centre of the edges and Na atom at centre of the cubic. The formula for the compound is:

- (A)  $\text{NaWO}_2$  (B)  $\text{NaWO}_3$  (C)  $\text{Na}_2\text{WO}_3$  (D)  $\text{NaWO}_4$

**Q.2** The coordination number of cation and anion in Fluorite  $\text{CaF}_2$  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

**Q.3** The interstitial hole is called tetrahedral because

- (A) It is formed by four spheres.  
(B) Partly same and partly different.  
(C) It is formed by four spheres the centres of which form a regular tetrahedron.  
(D) None of the above three.

**Q.4** The mass of a unit cell of CsCl corresponds to

- (A) 1  $\text{Cs}^+$  and 1  $\text{Cl}^-$  (B) 1  $\text{Cs}^+$  and 6  $\text{Cl}^-$   
(C) 4  $\text{Cs}^+$  and 4  $\text{Cl}^-$  (D) 8  $\text{Cs}^+$  and 1  $\text{Cl}^-$

**Q.5** Which one of the following schemes of ordering closed packed sheets of equal sized spheres do not generates close packed lattice.

- (A) ABCABC (B) ABACABAC  
(C) ABBAABBA (D) ABCBCABCBC

**Q.6** 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

**Q.7** The tetrahedral voids formed by ccp arrangement of  $\text{Cl}^-$  ions in rock salt structure are

- (A) Occupied by  $\text{Na}^+$  ions  
(B) Occupied by  $\text{Cl}^-$  ions  
(C) Occupied by either  $\text{Na}^+$  or  $\text{Cl}^-$  ions  
(D) Vacant

**Q.8** The number of nearest neighbours around each particle in a face-centred cubic lattice is

- (A) 4 (B) 6 (C) 8 (D) 12

**Q.9** 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<sub>2</sub>      (C) C<sub>2</sub>A<sub>3</sub>      (D) C<sub>3</sub>A<sub>2</sub>

**Q.10** 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<sub>2</sub>Y<sub>4</sub>Z      (B) XY<sub>2</sub>Z<sub>4</sub>      (C) X<sub>4</sub>Y<sub>2</sub>Z      (D) X<sub>4</sub>YZ<sub>2</sub>

**Q.11** The intermetallic compound LiAg crystallizes in cubic lattice in which both lithium and silver have coordination number of eight. The crystal class is

- (A) Simple cubic      (B) Body centred cubic  
(C) Face centred cubic      (D) None of these

**Q.12** NH<sub>4</sub>Cl crystallizes in a body-centred 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) 137.33 pm

## Previous Years' Questions

**Q.1** The coordination number of a metal crystallizing in a hexagonal close-packed structure is **(1999)**

- (A) 12      (B) 4      (C) 8      (D) 6

**Q.2** In a solid 'AB' having the NaCl structure, 'A' atoms occupy the corners of the cubic unit cell. If all the face-centred atoms along one of the axes are removed, then the resultant stoichiometry of the solid is **(2001)**

- (A) AB<sub>2</sub>      (B) A<sub>2</sub>B      (C) A<sub>4</sub>B<sub>3</sub>      (D) A<sub>3</sub>B<sub>4</sub>

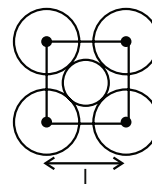
**Q.3** A substance A<sub>x</sub>B<sub>y</sub> crystallizes in a face centred cubic (fcc) lattice in which atoms 'A' occupy each corner of the cube and atom 'B' occupy the centres of each face of the cube. Identify the correct composition of the substance A<sub>x</sub>B<sub>y</sub>. **(2002)**

- (A) AB<sub>3</sub>      (B) A<sub>4</sub>B<sub>3</sub>  
(C) A<sub>3</sub>B      (D) Composition cannot be specified

**Q.4** Which of the following fcc structure contains cations in alternate tetrahedral voids? **(2005)**

- (A) NaCl      (B) ZnS      (C) Na<sub>2</sub>O      (D) CaF<sub>2</sub>

**Q.5** The packing efficiency of the two-dimensional square unit cell shown below is **(2010)**



- (A) 39.27%      (B) 68.02%      (C) 74.05%      (D) 78.54%

**Q.6 Statement-I:** In any ionic solid (MX) with Schottky defects, the number of positive and negative ions are same.

**Statement-II:** Equal number of cation and anion vacancies are present. **(2001)**

(A) Statement-I is true, statement-II is true, statement-II is the correct explanation of statement-I.

(B) Statement I is true, statement-II is true, statement-II is not the correct explanation of statement-I.

(C) Statement-I is true, statement-II is false.

(D) Statement-I is false, statement-II is true.

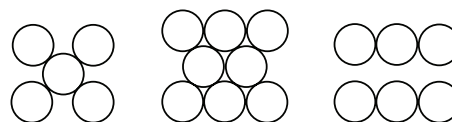
**Q.7** Sodium crystallizes in a bcc cubic lattice with the cell edge,  $a = 4.29 \text{ \AA}$ . What is the radius of sodium atom? **(1994)**

**Q.8** A metallic element crystallizes into a lattice containing a sequence of layers of ABABAB ..... Any packing of layers leaves out voids in the lattice. What percentage by volume of this lattice is empty space? **(1996)**

**Q.9** Chromium metal crystallizes with a body centred cubic lattice. The length of the unit edge is found to be 287 pm. Calculate the atomic radius. What would be the density of chromium in g/cm<sup>3</sup>? **(1997)**

**Q.10** A metal crystallizes into two cubic phases, face centred cubic (fcc) and body centred cubic (bcc), whose unit cell lengths are 3.5 and 3.0 Å, respectively. Calculate the ratio of densities of fcc and bcc. **(1999)**

**Q.11** The figures given below show the location of atoms in three crystallographic planes in a fcc lattice. Draw the unit cell for the corresponding structures and identify these planes in your diagram. **(2000)**





**Q.12** In a compound atoms of element Y from ccp lattice and those of element X occupy  $2/3^{\text{rd}}$  of tetrahedral voids. The formula of the compound will be **(2008)**

- (A)  $X_4Y_3$  (B)  $X_2Y_3$  (C)  $X_2Y$  (D)  $X_3Y_4$

**Q.13** The edge length of a face centered cubic cell of an ionic substance is 508 pm. If the radius of the cation is 110 pm, the radius of the anion is **(2010)**

- (A) 288 pm (B) 398 pm (C) 618 pm (D) 144 pm

**Q.14** Copper crystallizes in fcc with a unit cell length of 361 pm. What is the radius of copper atom **(2009)**

- (A) 108 pm (B) 127pm (C) 157pm (D) 181pm

**Q.15** Percentage of free space in cubic close packed structure and in body centred packed structure are respectively **(2010)**

- (A) 30% and 26% (B) 26% and 32%  
(C) 32% and 48% (D) 48% and 26%

**Q.16** In a face centred cubic lattice, atom A occupies the corner positions 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: **(2011)**

- (A)  $AB_2$  (B)  $A_2B_3$  (C)  $A_2B_5$  (D)  $A_2B$

**Q.17** 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: **(2012)**

- (A) 75 pm (B) 300 pm (C) 240 pm (D) 152 pm

**Q.18** CsCl crystallises in body centred cubic lattice. If 'a' is its edge length then which of the following expressions is correct? **(2014)**

- (A)  $r_{\text{Cs}^+} + r_{\text{Cl}^-} = 3a$  (B)  $r_{\text{Cs}^+} + r_{\text{Cl}^-} = \frac{3a}{2}$   
(C)  $r_{\text{Cs}^+} + r_{\text{Cl}^-} = \frac{\sqrt{3}}{2}a$  (D)  $r_{\text{Cs}^+} + r_{\text{Cl}^-} = \sqrt{3}a$

**Q.19** Sodium metal crystallizes in a body centred cubic lattice with a unit cell edge of 4.29 Å. The radius of sodium atom is approximately: **(2015)**

- (A) 1.86 Å (B) 3.22 Å (C) 5.72 Å (D) 0.93 Å

## JEE Advanced/Boards

### Exercise 1

**Q.1** A cubic solid is made up of two elements A and B. Atoms B are at the corners of the cube and A at the body centre. What is the formula of compound?

**Q.2** A compound alloy of gold and copper crystallizes in a cubic lattice in which gold occupies the lattice points at the corners of the cube and copper atom occupies the centres of each of the cube faces. What is the formula of this compound?

**Q.3** A cubic solid is made by atoms A forming close pack arrangement, B occupying one fourth of tetrahedral void and C occupying half of the octahedral voids. What is the formula of compound?

**Q.4** What is the percent by mass of titanium in rutile, a mineral that contain Titanium and oxygen, if structure can be described as a close packed array of oxide ions, with titanium in one half of the octahedral holes. What is the oxidation number of titanium?

**Q.5** Spinel is a important class of oxides consisting of two types of metal ions with the oxide ions arranged in ccp pattern. The normal spinel has one-eighth of the tetrahedral holes occupied by one type of metal ion and one half of the octahedral hole occupied by another type of metal ion. Such a spinel is formed by  $Zn^{2+}$ ,  $Al^{3+}$  and  $O^{2-}$ , with  $Zn^{2+}$  in the tetrahedral holes. Give the formulae of the spinel.

**Q.6** KF crystallizes in the NaCl type structure. If the radius of  $K^+$  ions 132 pm and that of  $F^-$  ion is 135 pm, what is the shortest K- F distance? What is the edge length of the unit cell? What is the closet K-K distance?

**Q.7** A closed packed structure of uniform spheres has the edge length of 534 pm. Calculate the radius of sphere, if it exist in

- (a) simple cubic lattice  
(b) BCC lattice  
(c) FCC lattice

**Q.8** Calculate the density of diamond from the fact that it has face centered cubic structure with two atoms per lattice point and unit cell edge length 3.569 Å.

**Q.9** An element crystallizes into a structure which may be described by a cubic type of unit cell having one atom on each corner of the cube and two atoms on one of its body diagonals. If the volume of this unit cell is  $24 \times 10^{-24} \text{ cm}^3$  and density of element is  $7.2 \text{ g cm}^{-3}$ , calculate the number of atoms present in 200 g of element.

**Q.10** Silver has an atomic radius of 144 pm and the density of silver is  $10.6 \text{ g cm}^{-3}$ . To which type of cubic crystal, silver belongs?

**Q.11** AgCl has the same structure as that of NaCl. The edge length of unit cell of AgCl is found to be 555 pm and the density of AgCl is  $5.561 \text{ g cm}^{-3}$ . Find the percentage of sites that are unoccupied.

**Q.12** Xenon crystallises in the face-centred cubic lattice and the edge of the unit cell is 620 pm. What is the nearest neighbour distance and what is the radius of Xenon atom?

**Q.13** The two ions  $A^+$  and  $B^-$  have radii 88 and 200 pm respectively. In the closed packed crystal of compound AB, predict the co-ordination number of  $A^+$ .

**Q.14** CsCl has the bcc arrangement and its unit cell edge length is 400 pm. Calculate the interionic distance in CsCl.

**Q.15** Gold crystallizes in a face centered cubic lattice. If the length of the edge of the unit cell is 407 pm, calculate the density of gold as well as its atomic radius assuming it to be spherical.

Atomic mass of gold = 197 amu.

**Q.16** The density of KBr is  $2.75 \text{ g cm}^{-3}$ . The length of the edge of the unit cell is 654 pm. Show that KBr has face centered cubic structure.

( $N = 6.023 \times 10^{23} \text{ mol}^{-1}$ , At. mass: K = 39, Br = 80)

**Q.17** An element crystallizes in a structure having FCC unit cell of an edge 200 pm. Calculate the density, if 200 g of this element contains  $24 \times 10^{23}$  atoms.

**Q.18** The effective radius of the iron atom is 1.42 Å. It has FCC structure. Calculate its density. (Fe = 56 amu)

**Q.19** A crystal of lead(II) sulphide has NaCl structure. In this crystal the shortest distance between  $Pb^{+2}$  ion and  $S^{2-}$  ion is 297 pm. What is the length of the edge of the unit cell in lead sulphide? Also calculate the unit cell volume.

**Q.20** If the length of the body diagonal for CsCl which crystallises into a cubic structure with  $Cl^-$  ions at the corners and  $Cs^+$  ions at the centre of the unit cells is 7 Å and the radius of the  $Cs^+$  ion is 1.69 Å, what is the radii of  $Cl^-$  ion?

**Q.21** Iron has body centered cubic lattice structure. The edge length of the unit cell is found to be 286 pm. What is the radius of an iron atom?

**Q.22** Cesium chloride forms a body centered cubic lattice. Cesium and chloride ions are in contact along the body diagonal of the unit cell. The length of the side of the unit cell is 412 pm and  $Cl^-$  ion has a radius of 181 pm. Calculate the radius of  $Cs^+$  ion.

**Q.23** In a cubic closed packed structure of mixed oxides the lattice is made up of oxide ions, one eighth of tetrahedral voids are occupied by divalent ions ( $A^{2+}$ ) while one half of the octahedral voids occupied trivalent ions ( $B^{3+}$ ). What is the formula of the oxide?

**Q.24** A solid  $A^+$  and  $B^-$  had NaCl type closed packed structure. If the anion has a radius of 250 pm, what should be the ideal radius of the cation? Can a cation  $C^+$  having a radius of 180 pm be slipped into the tetrahedral site of the crystal of  $A^+B^-$ ? Give reasons for your answer.

**Q.25** Calculate the value of Avogadro's number from the following data:

Density of NaCl =  $2.165 \text{ cm}^{-3}$

Distance between  $Na^+$  and  $Cl^-$  in

NaCl = 281 pm.

**Q.26** If the radius of  $Mg^{2+}$  ion,  $Cs^+$  ion,  $O^{2-}$  ion,  $S^{2-}$  ion and  $Cl^-$  ion are 0.65 Å, 1.69 Å, 1.40 Å, 1.84 Å, and 1.81 Å respectively. Calculate the co-ordination numbers of the cations in the crystals of MgS, MgO and CsCl.

**Q.27** Iron occurs as bcc as well as fcc unit cell. If the effective radius of an atom of iron is 124 pm. Compute the density of iron in both these structures.

**Q.28** KCl crystallizes in the same type of lattice as does NaCl. Given that  $\frac{r_{Na^+}}{r_{Cl^-}} = 0.5$  and  $\frac{r_{Na^+}}{r_{K^+}} = 0.7$  Calculate:

(a) The ratio of the sides of unit cell for KCl to that for NaCl and

(b) The ratio of densities of NaCl to that for KCl.

**Q.29** An element A (Atomic weight = 100) having bcc structure has unit cell edge length 400 pm. Calculate the density of A and number of unit cells and number of atoms in 10 gm of A.

## Exercise 2

### Single Correct Choice Type

**Q.1** The density of the  $\text{CaF}_2$  (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

**Q.2** 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.

**Q.3** A compound XY crystallizes in BCC lattice with unit cell edge length of 480 pm. If the radius of  $\text{Y}^-$  is 225 pm, then the radius of  $\text{X}^+$  is

- (A) 127.5 pm                      (B) 190.68 pm  
(C) 225 pm                        (D) 255 pm

**Q.4** In the closest packing of atoms A (radius:  $r_a$ ), the radius of atom B that can be fitted into tetrahedral voids is

- (A)  $0.155 r_a$                       (B)  $0.225 r_a$   
(C)  $0.414 r_a$                       (D)  $0.732 r_a$

**Q.5** In diamond, carbon atom occupies 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

**Q.6** Which of the following will show schottky defect

- (A)  $\text{CaF}_2$     (B) ZnS    (C) AgCl    (D) CsCl

**Q.7** Copper metal crystallizes in FCC lattice. Edge length of unit cell is 362 pm. The radius of largest atom that can fit into the voids of copper lattice without disturbing it.

- (A) 53 pm    (B) 45 pm    (C) 93 pm    (D) 60 pm

**Q.8** In FCC unit cell, what fraction of edge is not covered by atoms?

- (A) 0.134                              (B) 0.24  
(C) 0.293                              (D) None of these

### Multiple Correct Choice Type

**Q.9** 80.0 gm salt of weak base & strong acid XY is dissolved in water and formed 2 litre of aqueous solution. The pH of the resultant solution was found to be 5 at 298 K. If XY forms CsCl type crystal having

$$r_{\text{X}^+} \text{ (radius of } \text{X}^+) = 1.6 \text{ \AA}$$

$$\text{and } r_{\text{Y}^-} \text{ (radius of } \text{Y}^-) = 1.864 \text{ \AA}$$

then select write statement(s).

$$\text{(Given: } K_b(\text{XOH}) = 4 \times 10^{-5}; N_A = 6 \times 10^{23})$$

- (A) Molar mass of salt is 100 g/mol.  
(B) % Degree of dissociation of salt is 0.25.  
(C) Edge length of AB is 4 \AA.  
(D) Density of solid salt XY is 2 in gm/cc.

**Q.10** Select correct statement(s)

- (A) 8  $\text{Cs}^+$  ions occupy the second nearest neighbour location of a  $\text{Cs}^+$  ion  
(B) Each sphere is surrounded by six voids in two dimensional hexagonal close packed layer  
(C) If the radius of cations and anions are 0.3 \AA and 0.4 \AA then coordination number of cation in the crystal is 6.  
(D) In AgCl, the silver ion is displaced from its lattice position to an interstitial position such a defect is called a frenkel defect.

**Q.11** Which of the following statements is/are correct?

- (A) The coordination number of each type of ion in CsCl is 8.  
(B) A metal that crystallises in BCC structure has a coordination ion number 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. [ $r_{\text{Na}^+} = 95 \text{ pm}$ ;  $r_{\text{Cl}^-} = 181 \text{ pm}$ ]

**Q.12** Which of the following statements is/are correct?

- (A) In an anti-fluorite structure anions form FCC lattice and cations occupy all tetrahedral voids.
- (B) If the radius of cations and anions are  $0.2 \text{ \AA}$  and  $0.95 \text{ \AA}$  the coordination number of cation in the crystal is 4.
- (C) An atom/ion is transferred from a lattice site to an interstitial position in Frenkel defect.
- (D) Density of crystal always increases due to substitutional impurity defect.

### Assertion Reasoning Type

**Q.13 Statement-I:** Distance between nearest lattice points in BCC is greater than the same in FCC of the atoms of comparable size.

**Statement-II:** FCC has greater packing efficiency than BCC.

- (A) Statement-I is true, statement-II is true, statement-II is the correct explanation of statement-I.
- (B) Statement-I is true, statement-II is true, statement-II is not the correct explanation of statement-I.
- (C) Statement-I is true, statement-II is false.
- (D) Statement-I is false, statement-II is true.

**Q.14 Statement-I:** Increasing temperature increases the density of point defects.

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

- (A) Statement-I is true, statement-II is true, statement-II is the correct explanation of statement-I.
- (B) Statement-I is true, statement-II is true, statement-II is not the correct explanation of statement-I.
- (C) Statement-I is true, statement-II is false.
- (D) Statement-I is false, statement-II is true.

**Q.15 Statement-I:** Increase in dielectric constant is observed in Frenkel defect.

**Statement-II:** Anions come in interstitial space in case of Frenkel defect.

- (A) Statement-I is true, statement-II is true, and statement-II is the correct explanation of statement-I.
- (B) Statement-I is true, statement-II is true, and statement-II is not the correct explanation of statement-I.
- (C) Statement-I is true, statement-II is false.
- (D) Statement-I is false, statement-II is true.

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

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

- (A) Statement-I is true, statement-II is true, statement-II is the correct explanation of statement-I.
- (B) Statement-I is true, statement-II is true, statement-II is not the correct explanation of statement-I.
- (C) Statement-I is true, statement-II is false.
- (D) Statement-I is false, statement-II is true.

### Comprehension Type

**Paragraph 1:** Calcium crystallizes in a cubic unit cell with density  $3.2 \text{ g/cc}$ . Edge-length of the unit cell is  $437 \text{ picometre (pm)}$ .

**Q.17** If the metal is melted, density of the molten metal was found to be  $3 \text{ g/cc}$ . What will be the percentage of empty space in the melt?

- (A) 31%      (B) 36%      (C) 28%      (D) 49%

**Paragraph 2:** Silicon carbide (SiC) and diamond are covalent solids which crystallize in cubic structures. In SiC, carbon atoms occupy points of the face centred cubic lattice (FCC positions) and silicon atoms occupy half of the tetrahedral voids available. In diamonds, same position of the tetrahedral voids are occupied by other carbon atoms.

Also the density of SiC and diamond are  $3.2$  and  $3.6 \text{ g/cc}$  respectively. Answer the following four questions based on the above information: (M: Si = 28)

**Q.18** The radius of silicon atom is

- (A)  $0.76 \text{ \AA}$       (B)  $1.12 \text{ \AA}$       (C)  $3.54 \text{ \AA}$       (D)  $4.75 \text{ \AA}$

**Q.19** Which of the following will not change the density of SiC solid?

- (A) Substitution of some Si atoms by some carbon atoms
- (B) Schottky defects
- (C) Interchange of some Si atom by some C atom
- (D) Decreasing the temperature of solid

**Paragraph 3:** Calcium crystallizes in a cubic unit cell with density 3.2 g/cc. Edge-length of the unit cell is 437 picometer (pm).

**Q.20** The type of unit cell is

- (A) Simple cubic                      (B) BCC  
(C) FCC                                      (D) Edge-centred

**Q.21** The nearest neighbour distance is

- (A) 154.5 pm    (B) 309 pm    (C) 218.5 pm    (D) 260 pm

### Match the Columns

**Q.22**

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

**Q.23** [Distance in terms of Edge length of cube (a)]

Column I	Column II
(A) 0.866 a	(p) Shortest distance between cation and anion in CsCl structure.
(B) 0.707 a	(q) Shortest distance between two cations in $\text{CaF}_2$ structure
(C) 0.433 a	(r) Shortest distance between carbon atom in diamond
	(s) Shortest distance between two cation in rock salt structure

### Previous Years' Questions

**Q.1** Which of the following statement(s) is(are) correct? **(1998)**

- (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.

$$(r_{\text{Na}^+} = 95 \text{ pm}; r_{\text{Cl}^-} = 181 \text{ pm})$$

**Q.2** The correct statement(s) regarding defects in solids is(are). **(1999)**

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

**Paragraph 1:** 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 hexagon 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. Three spheres are then placed over the first layer so that they touch each other and represent the second layer. Each one of these three spheres touches three spheres of the bottom layer. Finally, the second layer is covered with a third layer that is identical to the bottom layer in relative position. Assume radius of every sphere to be 'r'. **(2008)**

**Q.3** The number of atoms in one of this hcp unit cell is

- (A) 4                      (B) 6                      (C) 12                      (D) 17

**Q.4** The volume of this hcp unit cell is

- (A)  $24\sqrt{2}r^3$     (B)  $16\sqrt{2}r^3$     (C)  $12\sqrt{2}r^3$     (D)  $\frac{26r^3}{3\sqrt{3}}$

**Q.5** The empty space in this hcp unit cell is

- (A) 74%                      (B) 47.6%                      (C) 32%                      (D) 26%

**6.** Match the crystal system/unit cells mentioned in column I with their characteristic features mentioned in column II. **(2007)**

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 system
(C) Cubic and tetragonal	(r) have only two crystallographic angles of $90^\circ$
(D) Hexagonal and monoclinic	(s) belongs to same crystal system

**Q.7** Silver (atomic weight =  $108 \text{ g mol}^{-1}$ ) has a density of  $10.5 \text{ g cm}^{-3}$ . The number of silver atoms on a surface of area  $10^{-12} \text{ m}^2$  can be expressed in scientific notation as  $y \times 10^x$ . The value of  $x$  is. **(2010)**

**Q.8** The number of hexagonal faces that are present in a truncated octahedron is. **(2011)**

**Q.9** Marbles of diameter 10 mm are to be put in a square area of side 40 mm so that their centers are within this area. Find the maximum number of marbles per unit area and deduce an expression for calculating it. **(2003)**

**Q.10** The crystal AB (rock salt structure) has molecular weight  $6.023y \text{ u}$ , where,  $y$  is an arbitrary number in u. If the minimum distance between cation and anion is  $y^{1/3} \text{ nm}$  and the observed density is  $20 \text{ kg/m}^3$ . Find the (a) density in  $\text{kg/m}^3$  and (b) type of defect. **(2004)**

**Q.11** An element crystallizes in fcc lattice having edge length 400 pm. Calculate the maximum diameter of atom which can be placed in interstitial site without distorting the structure. **(2005)**

**Q.12** The edge length of unit cell of a metal having molecular weight  $75 \text{ g/mol}$  is  $5 \text{ \AA}$  which crystallizes in cubic lattice. If the density is  $2 \text{ g/cc}$  then find the radius of metal atom. ( $N_A = 6 \times 10^{23}$ ). Give the answer in pm. **(2006)**

**Q.13** Match the crystal system/unit cells mentioned in column I with their characteristic features mentioned in column II. Indicate your answer by darkening the appropriate bubbles of the  $4 \times 4$  matrix given in the ORS. **(2007)**

Column I	Column II
(A) Simple cubic and face-centred cubic	(p) Have these cell parameters $a = b = c, \alpha = \beta = \gamma = 90^\circ$
(B) Cubic and rhombohedra	(q) Are two crystal systems
(C) Cubic and tetragonal	(r) Have only two crystallography
(D) Hexagonal and monoclinic	(s) Belong to same crystal system

**Paragraph 2:** 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. Three spheres are then placed over the first layer so that they touch each other and represent the second layer. Each one of these three spheres touches three spheres of the bottom layer. Finally, the second layer is covered with a third layer that is identical to the bottom layer in relative position. Assume radius of every sphere to be ' $r$ '.

**Q.14** The number of atoms on this HCP unit cell is **(2008)**

- (A) 4      (B) 6      (C) 12      (D) 17

**Q.15** The volume of this HCP unit cell is **(2008)**

- (A)  $24\sqrt{2}r^3$     (B)  $16\sqrt{2}r^3$     (C)  $12\sqrt{2}r^3$     (D)  $\frac{64r^3}{3\sqrt{3}}$

**Q.16** The empty space in this HCP unit cell is **(2008)**

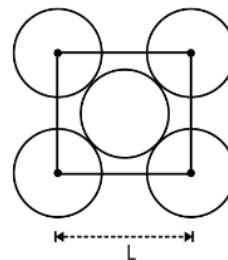
- (A) 75%      (B) 47.6%    (C) 32%      (D) 26%

**Q.17** The correct statement (s) regarding defects in solids is (are) **(2009)**

- (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

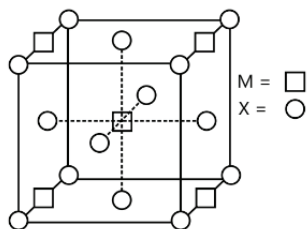
**Q.18** The coordination number of Al in the crystalline state of  $\text{AlCl}_3$  is **(2009)**

**Q.19** The packing efficiency of the two-dimensional square unit cell shown below is **(2010)**



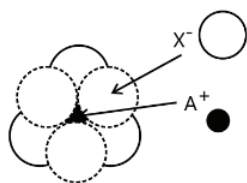
- (A) 39.27%      (B) 68.02%  
 (C) 74.05%      (D) 78.54%

**Q.20** A compound  $M_pX_q$  has cubic close packing (ccp) arrangement of arrangement of X. Its unit cell structure is shown below. **(2012)**



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

**Q.21** The arrangement of  $X^-$  ions around  $A^+$  ion in solid AX is given in the figure (not drawn to scale). If the radius of  $X^-$  is 250 pm, the radius of  $A^+$  is **(2013)**



- (A) 104 pm      (B) 125 pm      (C) 183 pm      (D) 57 pm

**Q.22** If the unit cell of a mineral has cubic close packed (ccp) array of oxygen atoms with m fraction of octahedral holes occupied by aluminium ions and n fraction of tetrahedral holes occupied by magnesium ions, m and n, respectively, are **(2015)**

- (A)  $\frac{1}{2}, \frac{1}{8}$       (B)  $1, \frac{1}{8}$       (C)  $\frac{1}{2}, \frac{1}{2}$       (D)  $\frac{1}{4}, \frac{1}{8}$

**Q.23** The **CORRECT** statement(s) for cubic close packed (ccp) three dimensional structure is(are) **(2016)**

- (A) The number of the nearest neighbours of an atom present in the topmost layer is 12  
 (B) The efficiency of atom packing is 74%  
 (C) The number of octahedral and tetrahedral voids per atom are 1 and 2, respectively  
 (D) The unit cell edge length is  $2\sqrt{2}$  times the radius of the atom

## MASTERJEE Essential Questions

### JEE Main/Boards

#### Exercise 1

Q.18      Q.25      Q.29

#### Exercise 2

Q.5      Q.10

#### Previous Years' Questions

Q.5      Q.7      Q.10

### JEE Advanced/Boards

#### Exercise 1

Q.5      Q.11      Q.15      Q.24

#### Exercise 2

Q.7      Q.10      Q.11      Q.22

#### Previous Years' Questions

Q.7      Q.9      Q.12

## Answer Key

### JEE Main/Boards

#### Exercise 1

**Q.6**  $M_2N_3$

**Q.8**  $2.85 \times 10^{24}$  atoms

**Q.10** 299.8 pm

**Q.12**  $1.2046 \times 10^{19}$  mol<sup>-1</sup>

**Q.14** 2.86 g cm<sup>-3</sup>

**Q.16** 144.2 pm

**Q.18**  $A_4B_3$

**Q.20** 0.523

**Q.22**  $ZnAl_2S_4$

**Q.24** 74%

**Q.30** 4

**Q.7** face-centred cubic

**Q.9** 2

**Q.11**  $4.348 \times 10^{-23}$  cm<sup>3</sup>

**Q.13** 52 u

**Q.15** 127.7 pm

**Q.17** 74.70 g mol<sup>-1</sup> or 74.70 u

**Q.19** 0.6709 g cm<sup>-3</sup>

**Q.21**  $M_4O_6$  or  $M_2O_3$

**Q.23** 60%; 4

**Q.25** 4.7 %

#### Exercise 2

**Q.1** B

**Q.2** C

**Q.3** C

**Q.4** A

**Q.5** C

**Q.6** B

**Q.7** D

**Q.8** D

**Q.9** C

**Q.10** A

**Q.11** B

**Q.12** A

#### Previous Years' Questions

**Q.1** A

**Q.2** D

**Q.3** A

**Q.4** B

**Q.5** D

**Q.6** A

**Q.7** 1.86 Å

**Q.8** 26%

**Q.9** 7.3 g/cc

**Q.10** 432:343

**Q.12** A

**Q.13** D

**Q.14** B

**Q.15** B

**Q.16** C

**Q.17** D

**Q.18** C

**Q.19** A

### JEE Advanced/Boards

#### Exercise 1

**Q.1** A-B

**Q.3**  $A_4B_2C_2$

**Q.5**  $ZnAl_2O_4$

**Q.7** 267 pm, 231.2 pm, 188.8 pm

**Q.9**  $3.472 \times 10^{24}$  atoms

**Q.2**  $AuCu_3$

**Q.4** 59.95%, +4

**Q.6** 267 pm, 534 pm, 378 pm

**Q.8** 3.5 g cm<sup>-3</sup>

**Q.10** FCC



- Q.11** 0.24%  
**Q.13** 6  
**Q.15** 19.4 g/cm<sup>3</sup>, 143.9 pm  
**Q.17** 41.67 cm<sup>-3</sup>  
**Q.19**  $a = 5.94 \times 10^{-8} \text{ cm}$ ,  $V = 2.096 \times 10^{-22} \text{ cm}^{-3}$   
**Q.21** 123.84 pm  
**Q.23** AB<sub>2</sub>O<sub>4</sub>  
**Q.25**  $6.01 \times 10^{23}$   
**Q.27** 7.887 g/cc, 8.59 gm/cm<sup>3</sup>  
**Q.29** 5.188 gm/cm<sup>3</sup>,  $6.023 \times 10^{22}$  atoms of A,  $3.0115 \times 10^{22}$  unit cells
- Q.12** 438.5 pm, 219.25 pm  
**Q.14** 346.4 pm  
**Q. 16** FCC  
**Q.18** 5.74 g cm<sup>-3</sup>  
**Q.20** 1.81 Å  
**Q.22** 175.8 pm  
**Q.24** 103.4 pm, No  
**Q.26** 4, 6, 8  
**Q.28** (a) 1.143, (b) 1.172

## Exercise 2

### Single Correct Choice Type

- Q.1** C      **Q.2** D      **Q.3** B      **Q.4** B      **Q.5** A      **Q.6** D  
**Q.7** A      **Q.8** C

### Multiple Correct Choice Type

- Q.9** A, C      **Q.10** B, D      **Q.11** A, C, D      **Q.12** A, C

### Assertion Reasoning Type

- Q.13** A      **Q.14** A      **Q.15** C      **Q.16** A

### Comprehension Type

- Q.17** A      **Q.18** B      **Q.19** C      **Q.20** C      **Q.21** D

### Match the Columns

- Q.22** A → r, s; B → p, q, r, s; C → q      **Q.23** A → p; B → q, s; C → r

## Previous Years' Questions

- Q.1** A, C, D      **Q.2** B, C      **Q.3** B      **Q.4** A      **Q.5** D  
**Q.6** A → p, s; B → p, q; C → q; D → q, r      **Q.7** 7      **Q.8** 8      **Q.9** 25  
**Q.10** (a) 5 kg/m<sup>3</sup>    (b) Metal excess defect      **Q.11** 117 pm      **Q.12** 217 pm  
**Q.13** A → p, s; B → p, q; C → q; D → q, r      **Q.14** B      **Q.15** A      **Q.16** D  
**Q.17** B, C      **Q.18** 6      **Q.19** D      **Q.20** B      **Q.21** A  
**Q.22** A      **Q.23** B, C, D

## Solutions

### JEE Main/Boards

#### Exercise 1

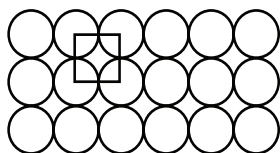
**Sol 1:** (i) See theory on page no. 19.20

(ii) See theory on page no. 19.22

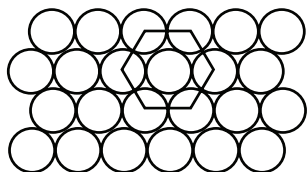
**Sol 2:** See theory on page no. 19.21

**Sol 3:** (a) When same property is measured in different direction in solid gives different value is called Anisotropy.

**Sol 4:** (a) Square close packing



Hexagonal close packing



(b) Coordination number of square close packing is 4.  
Coordination number of hexagonal close packing is 6.

**Sol 5:** (a) Schottky defect

(b) Frenkel defect

**Sol 6:** Effective number of atom in

$$\text{ccp} = \text{fcc} = 6 \times \frac{1}{2} + 8 \times \frac{1}{8}$$

$$= 4 = \text{N-atom}$$

Tetrahedral void = 8 (in fcc)

$$\text{Number of M-atom} = \frac{8}{3}$$

$$\text{So empirical formula} = \text{M}_8\text{N}_4 = \text{M}_2\text{N}_3$$

**Sol 7:** molar mass =  $2.7 \times 10^{-2}$  kg/mol = 27 gm/mol

Let's say in one cubic unit, there is Z-effective atoms

$$\frac{(z) \times \text{mass of one atom}}{\text{Volume of cell}} = \text{density}$$

$$\frac{(z) \times \frac{27}{6 \times 10^{23}} \times 10^{-3}}{(405 \times 10^{-12})^3} = 2.7 \times 10^{23}$$

$$Z = 4$$

So cubic unit would be fcc

**Sol 8:** Effective Atom = 2

$$\frac{2 \times (\text{mass of one atom})}{(300 \times 10^{-12})^3} = 5.200 \text{ kgm/m}^3$$

$$\text{Mass of one atom} = \frac{5.2 \times 10^6 \times 27 \times 10^{-30}}{2} \text{ gm}$$

$$= 70.2 \times 10^{-24} \text{ gm}$$

$$\text{Atoms in 200 gm} = \frac{200}{70.2 \times 10^{-24}} = 2.84 \times 10^{24} \text{ atoms}$$

**Sol 9:** Like question number 7, we suppose it has z-effective atoms in one unit cell

$$Z = \frac{(52 \times 1.66 \times 10^{-24})}{(298 \times 10^{-12})^3} = 7.2 \times 10^6 \text{ gm/m}^3$$

$$z = 2$$

So the unit would be bcc

**Sol 10:**  $4.12 \times 10^{24}$  atom = 200 gm

$$\text{Mass of one atom} = \frac{200}{4.12 \times 10^{24}} = 4.85 \times 10^{-23} \text{ gm}$$

Effectively number in fcc = 4

$$\frac{4 \times (4.85 \times 10^{-23})}{r^3} = 7.2 \text{ g/cm}^3$$

$$r = 300$$

**Sol 11:**  $Z_{\text{eff.}} = 2$

$$\frac{2 \times \left( \frac{6.94}{6.023 \times 10^{23}} \right)}{V} = 0.53 \text{ gm/cm}^3$$

$$V = 4.348 \times 10^{-23} \text{ cm}^3$$

**Sol 12:** One  $\text{Sr}^{2+}$  will replace 2  $\text{Na}^+$

So incoming of one  $\text{Sr}^{2+}$  will result into one cation vacancy

Let's say 100 moles are total

$$\text{In one mole, } \text{Sr}^{2+} = 6.023 \times 10^{23} \times \frac{2 \times 10^{-3}}{100}$$

$$\text{Cation vacancy} = 12.04 \times 10^{+18} = 1.204 \times 10^{19}$$

$$\text{Sol 13: } \frac{2 \times (\text{atomic mass})}{(2.88 \times 10^{-10})^3} = 7.2 \times 10^6 \text{ gm/m}^6$$

$$\text{Atomic mass} = 8.6 \times 10^{-23} \text{ gm}$$

$$\text{Atomic mass} \approx 52 \text{ amu}$$

$$\text{Sol 14: Density} = \frac{Z_{\text{eff}} (\text{mass of one atom})}{r^3}$$

$$= \frac{4 \times \left( \frac{208}{4.283 \times 10^{24}} \right)}{(4.08 \times 10^{-10})^3} = 2.86 \text{ gm/cm}^3$$

$$\text{Sol 15: } 8.930 \times 10^6 \text{ gm/m}^3 = \frac{4 \times \left( \frac{63.55}{6.023 \times 10^{23}} \right)}{a^3}$$

$$a^3 = \frac{4 \times 63.55}{8.93 \times 6.023} \times 10^{-29}$$

$$a = 3.6161 \text{ \AA}$$

$$\sqrt{2} a = 4r \text{ (in fcc structure, analyze diagonal of a face)}$$

$$r = 127.8 \text{ pm}$$

$$\text{Sol 16: } 19.3 \times 10^6 = \frac{4 \times \left( \frac{197}{6.023 \times 10^{23}} \right)}{a^3}$$

$$\text{Similarly } a = 407.74 \text{ pm}$$

$$\sqrt{2} a = 4r \text{ (in fcc structure)}$$

$$r = 144.15 \text{ pm}$$

$$\text{Sol 17: } 1.984 \times 10^6 = \frac{4 \times \left( \frac{M}{6.023 \times 10^{23}} \right)}{(6.3 \times 10^{-10})^3}$$

$$M = 74.69 \text{ gm}$$

**Sol 18:** In NaCl (fcc structure)

$$\text{Cl}^- \text{ at centre of face} = 6 \times \left( \frac{1}{2} \right) = 3$$

$$\text{Cl}^- \text{ at corners} = 8 \times \left( \frac{1}{8} \right) = 1$$

$$\text{Na}^+ \text{ at centre of edge} = 12 \times \left( \frac{1}{4} \right) = 3$$

$$\text{Na}^+ \text{ at centre of cube} = 1$$

If face centred, that is  $\text{Cl}^-$  is removed, along one axis.

$$\text{Then } \text{Cl}^- = 4 \times \left( \frac{1}{2} \right) + 8 \times \left( \frac{1}{8} \right) = 3$$

$$\text{Na}^+ = 3 + 1 = 4$$



Similarly  $\text{A}_4\text{B}_3$

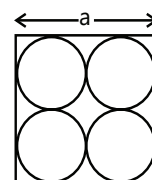
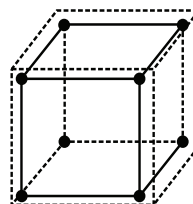
$$\text{Sol 19: Density} = \frac{4 \times (\text{mass of a molecule})}{abc}$$

$$= \frac{4 \times \left( \frac{21.76}{6.023 \times 10^{23}} \right)}{6.8 \times 4.4 \times 7.8 \times 10^{-30}} \text{ gm/m}^6$$

$$= 0.6709 \text{ gm/cm}^3$$

**Sol 20** Let's say radius of sphere = r

Side of cube that just encloses the sphere = 4r



$$\text{Volume} = (4R)^3 = 64 R^3$$

$$\text{Volume of sphere} = 8 \times \frac{4}{3} \pi R^3$$

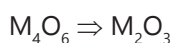
$$\text{Fraction} = \frac{8 \times \frac{4}{3} \pi}{64} = 52.35\%$$

**Sol 21:** Analyzing hcp structure

$$\text{O}^{2-} \text{ (in hcp array)} = 6$$

$$\text{Octahedral void (in hcp)} = 6$$

$$\text{M occupies } \frac{2}{3} \text{ rd of octahedral voids} = \frac{2}{3} \times 6 = 4$$



**Sol 22:** Closest packed array = fcc

$$\text{Zinc} = \frac{1}{8} \times (\text{Number pf tetrahedral void})$$

$$= \frac{1}{8} \times 8 = 1$$

$$\text{Aluminium} = \frac{1}{2} \times (\text{Number of octahedral void})$$

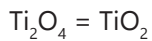
$$= \frac{1}{2} \times 4 = 2$$

$$S (\text{in fcc}) = 4$$



**Sol 23:** O (in fcc) = 4

$$\text{Ti} = \frac{1}{2} \times (\text{Number of Octahedral void}) = \frac{1}{2} \times 4 = 2$$



$$\% \text{ by mass of Ti} = \frac{48}{48 + 32} = 60 \%$$

$$\text{Ti oxidation state} = +4$$

**Sol 24:** Packing efficiency of hcp

$$Z_{\text{eff}} = 6$$

$$a = 2r (\text{side of hexagon})$$

$$b = (\text{height of hexagon}) = \frac{2\sqrt{2}}{\sqrt{3}} r$$

$$\text{So packing eff.} = \frac{6 \times \frac{4}{3} \pi (r)^3}{6 \times \frac{\sqrt{3}}{2} \times (2r)^2 \times \frac{2\sqrt{2}}{\sqrt{3}} r} = 74\%$$

Packing eff. For fcc

$$Z_{\text{eff}} = 4$$

$$a = \frac{4}{\sqrt{2}} r (\text{side of cubic})$$

$$\text{So packing eff.} = \frac{4 \times \left(\frac{4}{3} \pi r^3\right)}{16\sqrt{2}r^3} = 74\%$$

**Sol 25:** Let's suppose weight of Ge crystal is W

$$d_i = \text{initial density} = \frac{W}{V}$$

$$d_f = 0.96 d_i = 0.96 \frac{W}{V}$$

Volume is fixed so it implied boron decreases weight 4%

$$m_f = \text{mass final} = 0.96 W$$

$$xW + (1-x) \frac{W}{72.6} \times 11 = 0.96 W$$

$$x = 95.3\%$$

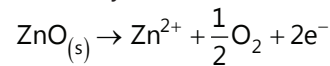
$$\% \text{ of vacancy} = 4.7\%$$

**Sol 26:** Refer theory.

**Sol 27:** (a) In metal on increasing temp, the alignment of electron get disturb due to excitation of electron due to which conductivity decrease while in case of semiconductor on increasing temp. electrons absorb energy and get excited to conduction band hence conductivity increases.

(b) Due to difference in size of atoms.

(c) On heating ZnO,  $\text{O}^{2-}$  ion is replaced by  $e^-$  due to which lattice contain free electrons to conduct electricity.



**Sol 28:** Refer theory

**Sol 29:** Refer theory

**Sol 30:** In ccp structure = fcc structure

Number of octahedral void

$$= \text{one at center of cube} + \text{At very edge centre, there is } \left(\frac{1}{4}\right)^{1/2}$$

$$\text{octahedral void} = 1 + 12 \left(\frac{1}{4}\right) = 4$$

Number of effective atom

$$= \text{at every corner, there is } \left(\frac{1}{8}\right)^{\text{th}} \text{ part of an atom} + \text{at}$$

$$\text{every center of face, there is } \left(\frac{1}{2}\right)^{\text{nd}} \text{ part of an atom}$$

$$= 8 \left(\frac{1}{8}\right) + 6 \left(\frac{1}{2}\right) = 4$$

## Exercise 2

$$\text{Sol 1: (B)} W = 8 \left(\frac{1}{8}\right) = 1, 0 = 12 \left(\frac{1}{4}\right) = 3$$

$$\text{Na} = 1$$



**Sol 2: (C)**  $\text{CaF}_2 \Rightarrow \text{Ca}^{2+}$  (in fcc) +  $\text{F}^-$

(at octahedral void)

$\text{CsCl} \Rightarrow \text{BCC} \Rightarrow \text{Cs}^+$  (at center) +  $\text{Cl}^-$

(at every corner)

Cordination number  $\Rightarrow 8 : 4$  ( $\text{CaF}_2$ )

$8 : 8$  ( $\text{CsCl}$ )

**Sol 3: (C)** Correct

**Sol 4: (A)**  $\text{CsCl} \Rightarrow \text{BCC} \Rightarrow \text{Cs}^+$  (at center) +  $\text{Cl}^-$  (at every corner)

$$1\text{Cs}^+ + \left(8 \times \frac{1}{8}\right)\text{Cl}^- = 1\text{Cs}^+ + 1\text{Cl}^-$$

**Sol 5: (C)** For close packing two same sheets cannot be together.

**Sol 6: (B)**  $\text{ZnS} \Rightarrow \text{S}^{2-}$  (fcc) +  $\text{Zn}^{2+}$  (occupies alternate tetrahedral void)

For occupation of tetrahedral void  $\frac{r_{\text{Zn}^{2+}}}{r_{\text{S}^{2-}}} = 0.225$

$$r_{\text{S}^{2-}} = 100 \text{ pm}$$

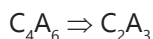
**Sol 7: (D)**  $\text{NaCl} \Rightarrow \text{Na}^+$  (at octahedral voids) +  $\text{Cl}^-$  (fcc structure).

**Sol 8: (D)** fcc  $\Rightarrow$  number of nearest neighbour around each particle = 12

**Sol 9: (C)** A  $\Rightarrow$  hcp effective number of atoms = 6

Octahedral void = 6

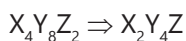
$$C = 6 \left(\frac{2}{3}\right) = 4$$



**Sol 10: (A)**  $Z_{\text{eff}}$ . For X  $\Rightarrow 8 \left(\frac{1}{8}\right) + 6 \left(\frac{1}{2}\right) = 4$

$Z_{\text{eff}}$ . For Y  $\Rightarrow 8$

$Z_{\text{eff}}$ . For Z  $\Rightarrow \frac{1}{2}(4) = 2$



**Sol 11: (B)** Co-ordination number = 8 = BCC

**Sol 12: (A)** Oppositely charged ions will be nearest atom.

Analyzing body (cubic) diagonal of BCC structure

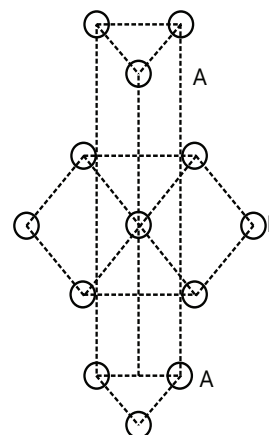
$$(r_{\text{NH}_4^+} + 2r_{\text{Cl}^-} + r_{\text{NH}_4^+}) = \sqrt{3} \quad (387)$$

$$2(r_{\text{NH}_4^+} + r_{\text{Cl}^-}) = 670.30 \text{ pm}$$

$$r_{\text{NH}_4^+} + r_{\text{Cl}^-} = 335.15 \text{ pm}$$

## Previous Years' Questions

**Sol 1: (A)** Three consecutive layers of atoms in hexagonal close packed lattice is shown below:



Atom X is in contact of 12 like atoms, 6 from layer B and 3 from top and bottom layers A each.

**Sol 2: (D)** In  $\text{NaCl}$ ,  $\text{Na}^+$  occupies body centre and edge centres while  $\text{Cl}^-$  occupies corners and face centres, giving four  $\text{Na}^+$  and four  $\text{Cl}^-$  per unit cell. In the present case, A represent  $\text{Cl}^-$  and B represents  $\text{Na}^+$ . Two face centres lies on one axis.

$$\Rightarrow \text{Number of A removed} = 2 \times \frac{1}{2} = 1$$

Number of B is removed because it is not present on face centres.

$$\Rightarrow \text{A remaining} = 4 - 1 = 3$$

B remaining = 4

$$\Rightarrow \text{Formula} = \text{A}_3\text{B}_4$$

**Sol 3: (A)** In cubic system, a corner contribute  $\frac{1}{8}$ th part of atom to one unit cell and a face centre contribute  $\frac{1}{2}$  part of atom to one unit cell. Therefore,

$$\text{Number of A per unit cell} = \frac{1}{8} \times 8 = 1$$

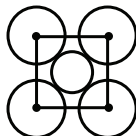
$$\text{Number of B per unit cell} = \frac{1}{2} \times 6 = 3$$

$$\Rightarrow \text{Formula} = \text{AB}_3$$

**Sol 4: (B)** In ZnS,  $S^{2-}$  (sulphide ions) are present at fcc position giving four sulphide ions per unit cell. To comply with 1 : 1 stoichiometry, four  $Zn^{2+}$  ions must be present in four alternate tetrahedral voids out of eight tetrahedral voids present.

In NaCl,  $Na^+$  ions are present in octahedral voids while in  $Na_2O$ ,  $Na^+$  ions are present in all its tetrahedral voids giving the desired 2 : 1 stoichiometry. In  $CaF_2$ ,  $Ca^{2+}$  occupies fcc positions and all the tetrahedral voids are occupied by fluoride ions.

**Sol 5: (D)**



Contribution of circle from corner of square =  $\frac{1}{4}$

⇒ Effective number of circle per square

$$= \frac{1}{4} \times 4 + 1(\text{at centre}) = 2$$

⇒ Area occupied by circle =  $2\pi r^2$ ;

$r$  = radius.

Also, diagonal of square  $4r = \sqrt{2}L$ ,

where  $L$  = side of square.

⇒ Packing fraction

$$= \frac{\text{Area occupied by circle}}{\text{Area of square}}$$

$$= \frac{2\pi r^2}{L^2} = \frac{2\pi r^2}{8r^2} = \frac{\pi}{4} = 0.7854$$

⇒ % packing efficiency = 78.54%

**Sol 6: (A)** In ionic solid MX (1 : 1 solid), same number of  $M^{n+}$  and  $X^{n-}$  ions are lost in Schottky defect to maintain electro-neutrality of solid.

**Sol 7:** In bcc arrangement of atoms:  $4r = \sqrt{3}a$ , atoms on body diagonal remain in contact

$$\Rightarrow r = \frac{\sqrt{3}a}{4} = \frac{\sqrt{3} \times 4.29}{4} = 1.86 \text{ \AA}$$

**Sol 8:** The given arrangement: ABABAB..... represents hexagonal close-packed unit cell in which there are six atoms per unit cell. Also, volume of unit cell =  $24\sqrt{2}r^3$ .

⇒ Packing fraction

$$= \frac{\text{Volume occupied by atoms}}{\text{Volume of unit cell}}$$

$$= 6 \times \frac{4}{3} \pi r^3 \times \frac{1}{24\sqrt{2}r^3} = 0.74$$

⇒ Percent empty space

$$= 100(1 - 0.74) = 26\%$$

**Sol 9:** In bcc unit cell  $4r = \sqrt{3}a$

$$\Rightarrow r(\text{Cr}) = \frac{\sqrt{3}}{4}a = \frac{\sqrt{3}}{4} \times 287 \text{ pm} = 124.3 \text{ pm}$$

$$\text{Density of solid} = \frac{NM}{N_A \cdot a^3}$$

$N$  = Number of atoms per unit cell

$M$  = Molar mass

$a^3$  = Volume of cubic unit cell

$N_A$  = Avogadro's number

$$= \frac{2 \times 52 \text{ g}}{6.023 \times 10^{23}} \times \left( \frac{1}{2.87 \times 10^{-8} \text{ cm}} \right)^3 = 7.3 \text{ g/cm}^3$$

**Sol 10:** We have, F.C.C unit cell length =  $3.5 \text{ \AA}$ ,

B.C.C unit cell length =  $3.0 \text{ \AA}$

Now no. of atoms for F.C.C( $n_1$ ) = 4;

$$V_1 = a^3 = (3.5 \times 10^{-8})^3$$

Now no. of atoms for B.C.C( $n_2$ ) = 2

$$V_2 = a^3 = (3.0 \times 10^{-8})^3$$

$$\text{Density in F.C.C} = \frac{(n_1 \times \text{At. wt})}{(V_1 \times \text{Av. No})}$$

$$\text{Density in B.C.C} = \frac{(n_2 \times \text{At. wt})}{(V_2 \times \text{Av. No})}$$

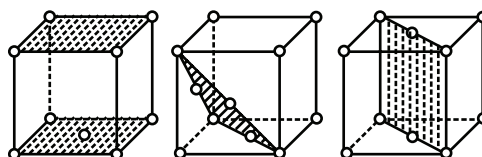
Therefore,

$$\frac{D_{\text{F.C.C}}}{D_{\text{B.C.C}}} = (n_1 / n_2) \times (V_1 / V_2)$$

$$= (4 / 2) \times (3.0 \times 10^{-8})^3 / (3.5 \times 10^{-8})^3$$

$$= 432 : 343$$

**Sol 11:**



**Sol 12: (A)** No. of atoms of Y = 4

$$\text{No. of atoms of X} = \frac{2}{3} \times 8$$

Formula of compound will be  $X_4Y_3$

**Sol 13: (D)** For an ionic substance in FCC arrangement,

$$2(r^+ + r^-) = \text{edge length}$$

$$2(110 + r^-) = 508$$

$$r^- = 144 \text{ pm}$$

**Sol 14: (B)** For F.C.C

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

$$r = \frac{\sqrt{2}a}{4} = \frac{\sqrt{2} \times 361}{4} = 127 \text{ pm}$$

**Sol 15: (B)** Packing fraction of cubic close packing and body centred packing are 0.74 and 0.68 respectively.

$$\text{Sol 16: (C) Effective no. of A atoms} = \frac{1}{8} \times 8 = 1$$

$$\text{Effective no. of B atoms} = \frac{1}{2} \times 5 \text{ (One is missing)} = \frac{5}{2}$$

Therefore formula is  $A_1B_{\frac{5}{2}} = A_2B_5$

**Sol 17: (D)** For BCC,  $\sqrt{3}a = 4r$

$$r = \frac{\sqrt{3} \times 351}{4} = 152 \text{ pm}$$

$$\text{Sol 18: (C) } 2r_{\text{Cl}^-} + 2r_{\text{Cs}^+} = \sqrt{3}a$$

$$r_{\text{Cl}^-} + r_{\text{Cs}^+} = \frac{\sqrt{3}a}{2}$$

$$\text{Sol 19: (A) } R = \frac{\sqrt{3}}{4}a = 1.86 \text{ \AA}$$

## JEE Advanced/Boards

### Exercise 1

**Sol 1:** AB = (CsCl type structure)

$$\text{Sol 2: Gold (Au)} = 8 \times \frac{1}{8} = 1$$

$$\text{Copper (Cu)} = \left(\frac{1}{2}\right) \times 6 = 3$$

$\text{AuCu}_3$

$$\left. \begin{array}{l} \text{Sol 3: A = ccp = fcc} = 4 \\ \text{B} = \frac{1}{4}(8) = 2 \\ \text{C} = \frac{1}{2}(4) = 2 \end{array} \right\} Z_{\text{eff.}} = \text{effective number of atoms}$$

$\text{A}_4\text{B}_2\text{C}_2$

$$\left. \begin{array}{l} \text{Sol 4: O}^{2-} = \text{ccp} = 4 \\ \text{Ti} = \frac{1}{2}(4) = 2 \end{array} \right\} Z_{\text{eff.}} = \text{effective number of atoms}$$

$\text{TiO}_2$

↓

+4

$$\left. \begin{array}{l} \text{Sol 5: O}^{2-} = \text{ccp} = 4 \\ \text{A} = \frac{1}{8} \times (8) = 1 = \text{Zn}^{2+} \\ \text{B} = \frac{1}{2}(4) = 2 = \text{Al}^{3+} \end{array} \right\} Z_{\text{eff.}} = \text{effective number of atoms}$$

$\text{ZnAl}_2\text{O}_4$

**Sol 6:** Analyzing one edge of FCC (KF) structure

$$2(r_+ + r_-) = a$$

$$r_+ + r_- = \text{shortest KF - distance} = 132 + 135 = 267 \text{ pm}$$

$$a = 534 \text{ pm}$$

$$\text{Closest K - K distance} = \frac{\sqrt{2}a}{2} = 377.6 \text{ pm}$$

**Sol 7:** (a)  $2r = a$

$$r = 267 \text{ pm}$$

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

$$r = 231.22 \text{ pm}$$

(c) FCC

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

$$R = 188.8 \text{ pm}$$

$$\text{Sol 8: density} = \frac{8 \left( \frac{12}{6.023 \times 10^{23}} \right)}{(3.569 \times 10^{-10})^3}$$

$$(Z_{\text{eff.}} = 8 \text{ for fcc of diamond}) = 3.5 \text{ gm/cm}^2$$

**Sol 9:** Mass of unit cell =  $7.2 \times 24 \times 10^{-24}$

$$= 17.28 \times 10^{-23} \text{ gm}$$

Number of unit cell in 200 gm

$$= \frac{200}{17.28 \times 10^{-23}} = 11.57 \times 10^{23}$$

$$\text{Number of atoms in one unit cell} = 8 \times \left(\frac{1}{8}\right) + 2 = 3$$

So, Number of atoms in 200 gm of solid =  $3 \times 11.57 \times 10^{23}$

$$= 3.472 \times 10^{24} \text{ atom}$$

**Sol 10:**  $r_{\text{Ag}} = 144 \text{ pm}$

$$\text{Density} = \frac{Z_{\text{eff.}} \times \left(\frac{108}{6.023 \times 10^{23}}\right)}{a^3} = 1.6 \times 10^6$$

$$\frac{a^3}{Z_{\text{eff.}}} = 16.91 \times 10^{-30}$$

$$\Rightarrow a = (Z_{\text{eff.}} \times 16.91 \times 10^6)^{1/3} \text{ pm}$$

**Case I: Simple cubic**

$$Z_{\text{eff.}} = 1$$

$$a = 2r$$

Which does not satisfies

**Case II : BCC**

$$Z_{\text{eff.}} = 2$$

$$a = 323.38 \text{ pm}$$

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

$$r = 140 \text{ pm}$$

Which does not satisfy

**Case III : FCC**

$$Z_{\text{eff.}} = 4$$

$$a = 407.44 \text{ pm}$$

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

$$r = 144 \text{ pm}$$

So, the structure will be FCC

**Sol 11:**  $a = 555 \text{ pm}$

NaCl in FCC =  $\text{Na}_4\text{Cl}_4$

$$5.561 \times 10^6 = \frac{\text{Mass of unit cell}}{(5.55 \times 10^{-10})^3}$$

$$95 \times 10^{-23} = \text{mass of unit cell}$$

$$95.06 \times 10^{-23} = \text{mass of unit cell}$$

Mass of unit cell (theoretical)

$$= 4 \times \left(\frac{108 + 35.5}{6.023 \times 10^{23}}\right) = 95.301 \times 10^{-23} \text{ gm}$$

$$\% \text{ of sites} = \frac{95.30 - 95.06}{95.30} \times 100 = 0.24 \%$$

**Sol 12:** Nearest height distance =  $\frac{\sqrt{2}a}{2} = 2r$

$$= 438.40 \text{ pm}$$

$$r = 219.2 \text{ pm}$$

$$\text{Sol 13: } \frac{r_{\text{A}^+}}{r_{\text{B}^-}} = \frac{88}{200} = 0.44 > 0.414$$

So it will occupy octahedral void

So coordination number would be = 6

**Sol 14:**  $\sqrt{3} a = 2(r_+ + r_-)$

$$(r_+ + r_-) = \frac{\sqrt{3} \times 400}{2}$$

$$r_+ + r_- = 346.41 \text{ pm}$$

**Sol 15:**  $a = 407 \text{ pm}$

$$\text{Density} = \frac{4 \times \left(\frac{197}{6.02 \times 10^{23}}\right)}{(4.07 \times 10^{-10})^3} = 19.40 \text{ gm/cm}^3$$

In fcc,  $\sqrt{2} a = 4r$

$$R = 143.9 \text{ pm}$$

$$\text{Sol 16: } 2.75 \times 10^6 = \frac{Z_{\text{eff.}} \left(\frac{39 + 80}{6.023 \times 10^{23}}\right)}{(6.54 \times 10^{-10})^3}$$

$$Z_{\text{eff.}} \sim 4$$

FCC structure

$$\text{Sol 17: Density} = \frac{\text{mass}}{\text{volume}} = \frac{200}{\text{volume of 200gm}}$$

$$4 \text{ atoms then volume} = (2.00 \times 10^{-10})^3 \text{ m}^3$$

$$24 \times 10^{23} \text{ atom then volume} = \frac{8 \times 10^{-30}}{4} \times 24 \times 10^{23} \text{ m}^3$$

$$\text{Density} = \frac{200 \times 4}{28 \times 10^{-30} \times 24 \times 10^{23}} \text{ gm/m}^3 = 41.67 \text{ gm/m}^3$$

**Sol 18:**  $\sqrt{2} a = 4r$

$$a = 2\sqrt{2} r = 4.016 \text{ \AA}$$



$$\text{Density} = \frac{4 \times \left( \frac{56}{6.023 \times 10^{23}} \right)}{10^{-30} \times (4.016)^3} \text{ gm/m}^6 = 5.74 \text{ gm/m}^6$$

**Sol 19:**  $(r_{\text{pb}^{2+}} + r_{\text{S}^{2-}}) = 297 \text{ pm}$

PbS  $\Rightarrow$  NaCl type structure

Analyzing edge in Rock Salt Structure

$$a = 2(r_{\text{pb}^{2+}} + r_{\text{S}^{2-}}) = 594 \text{ pm}$$

$$V = a^3 = 209.5 \times 10^{-30} \text{ m}^3$$

**Sol 20:**  $\sqrt{3} a = 2(r_{\text{Cs}^+} + r_{\text{Cl}^-}) = 7 \text{ \AA}$

$$\sqrt{3} = 2(1.69 + r_{\text{Cl}^-}) = 7 \text{ \AA}$$

$$r_{\text{Cl}^-} = 1.81 \text{ \AA}$$

**Sol 21:**  $\sqrt{3} a = 4r_{\text{Fe}}$

$$r_{\text{Fe}} = 123.8 \text{ pm}$$

**Sol 22:**  $\sqrt{3} a = 2(r_{\text{Cs}^+} + r_{\text{Cl}^-})$

$$\sqrt{3}(412) = 2(r_{\text{Cs}^+} + 181)$$

$$r_{\text{Cs}^+} = 175.8 \text{ pm}$$

**Sol 23:** ccp = fcc

Tetrahedral void = 8 ;

Octahedral void = 4

$$Z_{\text{eff}} = \text{effective number of atoms} = 4 = 8 \times \left( \frac{1}{8} \right) + 6 \times \left( \frac{1}{2} \right)$$

$$A^{2+} = \frac{1}{8}(8) = 1$$

$$B^{3+} = \frac{1}{2}(4) = 2$$

$$O^{2-} (\text{fcc}) = 4$$



**Sol 24:** In NaCl structure,  $\text{Na}^+$  occupies tetrahedral

voids, so radius of cation  $\frac{r_+}{r_-} = (\sqrt{2} - 1)$

$$r_+ = 103.5 \text{ pm}$$

It  $r_+ = 180 \text{ pm}$  then  $\frac{r_+}{r_-} = 0.72$

No, it can not be slipped into tetrahedral void

Because for tetrahedral voids

$$0.225 < \frac{r_+}{r_-} < 0.414$$

**Sol 25:** Density =  $\frac{\text{Mass of unit cell}}{\text{Volume of unit cell}}$

$$2(r_{\text{Na}^+} + r_{\text{Cl}^-}) = a$$

$$a = 2 \times 281 = 562 \text{ pm}$$

$$2.165 \times 10^6 = \frac{4 \times (\text{mass of a molecule})}{(5.62 \times 10^{-10})^3}$$

Mass of a molecule

$$= \frac{23 + 35.5}{\text{Avogadro's number}} = 96.07 \times 10^{-24}$$

$$N_A = \text{Avogadro's number} = 6.089 \times 10^{23}$$

**Sol 26:** MgS

$$\frac{r_+}{r_-} = \frac{0.65}{1.84} = 0.35$$

$$0.225 < \frac{r_+}{r_-} < 0.414 \text{ (Tetrahedral void)}$$

$\text{Mg}^{2+}$  will occupy tetrahedral void (alternate)

So the coordination number = 4

MgO

$$\frac{r_+}{r_-} = \frac{0.65}{1.40} = 0.464$$

$$0.414 < \frac{r_+}{r_-} < 0.732$$

So  $\text{Mg}^{2+}$  will occupy octahedral void

Coordination number = 4

CsCl

$$\frac{r_+}{r_-} = \frac{1.69}{1.81} = 0.933$$

$$0.732 < \frac{r_+}{r_-} < 1$$

So  $\text{Cs}^+$  will occupy center position in BCC structure

Coordination number = 8

**Sol 27:** BCC

$$r = 124 \text{ pm}$$

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

$$a = 286.3 \text{ pm}$$

$$\text{density} = \frac{2 \times \left( \frac{56}{6.02 \times 10^{23}} \right)}{(2.863 \times 10^{-10})^3} = 7.924 \text{ gm/cm}^3$$

FCC

$$r = 124 \text{ pm}$$

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

$$a = 350.72 \text{ pm}$$

$$\text{density} = \frac{4 \times \left( \frac{56}{6.023 \times 10^{23}} \right)}{(3.5072 \times 10^{-10})^3} = 8.620 \text{ gm/cm}^3$$

$$\text{Sol 28: } r_{\text{K}^+} = \frac{r_{\text{Na}^+}}{0.7}$$

$$\frac{r_{\text{K}^+}}{r_{\text{Cl}^-}} = \frac{r_{\text{Na}^+}}{(0.7)r_{\text{Cl}^-}} = \frac{5}{7} = 0.714$$

$$(a) \text{ Sides of KCl} = 2(r_{\text{K}^+} + r_{\text{Cl}^-}) = 2 \left( \frac{5}{7} + 1 \right) r_{\text{Cl}^-}$$

$$\text{Sides of NaCl} = 2(r_{\text{Na}^+} + r_{\text{Cl}^-}) = 2(1.5) r_{\text{Cl}^-}$$

$$\text{Ratio} = \frac{12}{7 \times 1.5} = \frac{8}{7} = 1.143$$

$$(b) \text{ Ratio density} = \frac{d_1}{d_2} = \frac{4 \times \frac{M_{\text{NaCl}}}{(r_{\text{NaCl}})^3}}{4 \times \frac{M_{\text{KCl}}}{(r_{\text{KCl}})^3}}$$

$$= \frac{M_{\text{NaCl}}}{M_{\text{KCl}}} \left( \frac{r_{\text{KCl}}}{r_{\text{NaCl}}} \right)^3$$

$$= \frac{58.5}{74.5} \left( \frac{8}{7} \right)^3 = 1.1725$$

**Sol 29:** BCC structure

Effective number of atoms = 2

$$\text{Density} = \frac{2 \times \left( \frac{100}{6.023 \times 10^{23}} \right)}{(4 \times 10^{-10})^3} = 5.188 \text{ gm/cm}^3$$

$$\text{Volume of 10 gm} = \frac{10}{5.188} = 1.927 \text{ cm}^3$$

$$= 1.927 \times 10^{-6} \text{ cm}^3$$

$$\text{Volume of one unit} = (4 \times 10^{-10})^3 = 64 \times 10^{-30} \text{ cm}^3$$

$$\text{Number of unit cells} = \frac{1.927 \times 10^{-6}}{64 \times 10^{-30}} = 0.301 \times 10^{23}$$

$$\text{Number of atoms} = 6.023 \times 10^{22} \text{ atoms}$$

**Exercise 2****Single Correct Choice Type****Sol 1: (C)**  $\text{CaF}_2 = \text{Ca}^{2+}$  (in fcc structure) +  $\text{F}^-$ 

(at tetrahedral void)

$$= 4 + 8 = 12 \text{ atoms} = 4 \text{ molecules}$$

$$3.18 \times 10^6 = \frac{4 \times \left( \frac{78}{6.023 \times 10^{23}} \right)}{a^3} \Rightarrow a = 546 \text{ pm}$$

**Sol 2: (D)**

(a) False each has co-ordination number = 6

(b) False

(c) False

(d) True

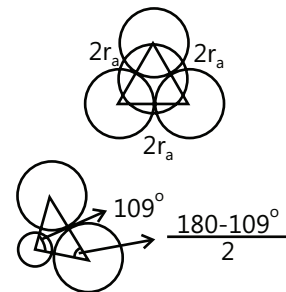
Both should have equal co-ordination number

**Sol 3: (B)** Analyzing cubic diagonal in three dimension

$$\left( \frac{r_{\text{y}^-} + 2r_{\text{x}^+} + r_{\text{y}^-}}{\sqrt{3}} \right) = 480 \text{ pm}$$

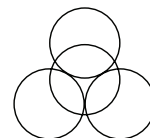
$$r_{\text{x}^+} + 225 = 240 \sqrt{3}$$

$$r_{\text{x}^+} = 190 \text{ pm}$$

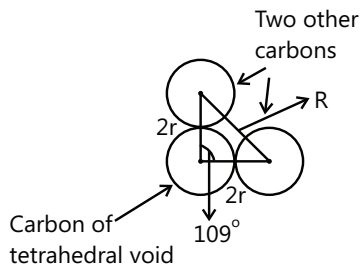
**Sol 4: (B)** Closest packing  $\Rightarrow$  fcc

$$\frac{2r_a}{\sin 109^\circ} = \frac{r_a + r_b}{\sin(35.5^\circ)}$$

$$r_b = 0.225r_a$$

**Sol 5: (A)** Analyzing unit of tetrahedral void

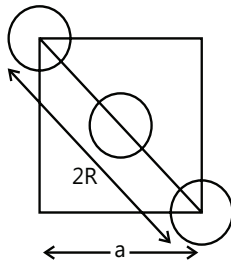
In the shown fig. of four carbon atoms, there is one more carbon atom which is in tetrahedral void of the group. It is in touch with all other carbon atoms. None of the 4 carbon-atoms touches each other.



$$\frac{R}{\sin 109^\circ} = \frac{2r}{\sin\left(\frac{180-109^\circ}{2}\right)}$$

$$R = 3.256 r_c$$

Face of cubic



$$\sqrt{2} a = 2R$$

$$R = \frac{a}{\sqrt{2}}$$

$$3.256 r_c = \frac{356}{\sqrt{2}}$$

$$r_c = 77.0 \text{ pm}$$

**Sol 6: (D)** Schottky defect appears in molecules which have same size of ions & have high co-ordination. Thus, CsCl will show this defect.

**Sol 7: (A)** Edge length =  $a = 362 \text{ pm}$

In fcc unit, analyzing face diagonal

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

radius of copper

$$r = \frac{356}{2\sqrt{2}} = 128 \text{ pm}$$

fcc has two types of void

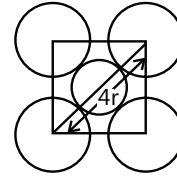
$\Rightarrow$  tetrahedral, octahedral

Octahedral void will allow for largest radius of atom without any disturbance

$$\frac{r_A}{r_{\text{Cu}}} = 0.414$$

$$\Rightarrow r_A = 53 \text{ pm}$$

**Sol 8: (C)** Face of FCC unit cell:



$$\text{Edge length} = \frac{4r}{\sqrt{2}} = 2\sqrt{2} r$$

$$\text{Covered length} = 2r$$

$$\text{Fraction cover} = \frac{2r}{2\sqrt{2}r} = 70\%$$

$$\text{Fraction not covered} = 100 - 70.7 = 29.3\%$$

**Multiple Correct Choice Type**

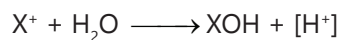
**Sol 9: (A, C)** XY has CsCl type structure

$$\text{So } 2(r_{x^+} + r_{y^-}) = \sqrt{3} a$$

$$A = 4\text{\AA}$$

Let's suppose molecular weight of XY = M

$$\text{So } [\text{XY}] = \frac{80}{2 \times M} = C$$



c

$$c(1-\alpha) \qquad c\alpha \qquad c\alpha$$

$$\frac{K_w}{K_b} = \frac{[\text{XOH}][\text{H}^+]}{[\text{X}^+]}$$

$$[\text{H}^+] = 10^{-5}$$

$$\frac{10^{-14}}{4 \times 10^{-5}} = \frac{c\alpha}{c(1-\alpha)} \times 10^{-5}$$

$$\alpha \sim \frac{1}{4} \times 10^{-4}$$

$$[\text{H}^+] = c\alpha = 10^{-5}$$

$$C = \frac{10^{-5}}{(1/4) \times 10^{-4}}$$

$$C = 0.4$$

$$\frac{80}{2M} = 0.4$$

$$M = 100 \text{ gm/mole}$$

$$\text{Density} = \frac{1 \times \left( \frac{100}{6.02 \times 10^{23}} \right)}{(4 \times 10^{-10})^3} = 2.6 \text{ gm/cm}^3$$

**Sol 10: (B, D)**

- (A) Wrong. Analyzing CsCl structure  
 (B) Voids on center of edge so six void  
 (C) Co-ordination will not be affected.  
 (D) Correct

**Sol 11: (A, C, D)**

- (A) Correct  
 (B) No, co-ordination in BCC structure = 8  
 (C) Yes

$$(D) \frac{r_{\text{Na}^+}}{r_{\text{Cl}^-}} = \frac{95}{181} = 0.524 > 0.414$$

$$\text{So length of edge} = 2(r_{\text{Na}^+} + r_{\text{Cl}^-}) \\ = 552 \text{ pm}$$

**Sol 12: (A, C)**

- (A) Correct  
 (B)  $\frac{r_+}{r_-} = \frac{0.2}{0.95} = 0.210 < 0.225$   
 $\frac{r_+}{r_-} > 0.155$

It will occupy trigonal void

Co-ordination number = 3

- (C) Correct  
 (D) No, It depends on other atom that is coming

**Assertion Reasoning Type**

**Sol 13: (A)** Statement-II correct

Statement-I BCC  $\Rightarrow 4r = \sqrt{3} a$

$$a = \frac{4r}{\sqrt{3}}$$

$$\text{FCC} \Rightarrow \sqrt{2} a = 4r$$

$$a = \frac{4r}{\sqrt{2}}$$

BCC > FCC (distance between nearest lattice points)

**Sol 14: (A)** Statement-II  $\Delta G = \Delta H - T\Delta S$

$\Delta H$  for formation of point defect  $> 0$

$\Delta S > 0$

So hence increasing T leads to decrease in G

So increasing temperature, we will get more point defect.

Statement-II is explaining statement-I

**Sol 15: (C)** Statement-II is wrong. Because cations comes in interstitial space because of small size.

**Sol 16: (A)** Both are correct, statement-II is explaining statement-I

**Comprehension Type**

**Sol 17: (A)** In fcc packing efficiency = 74%

Let's say total volume of the solid = V

Mass = (3.2) V

Now, after melting, mass would be same.

$$3 = \frac{(3.2)V}{V_f}$$

$$V_f = 1.066 V$$

$$\text{So, final packing efficiency} = \frac{(0.74)V}{(1.066V)} = 69.3\%$$

Hence empty space ~ 31%

**Sol 18: (B)** SiC  $\Rightarrow$  C = fcc

Si = at half of tetrahedral voids

Molecular weight = 28

Diamond  $\Rightarrow$  C = fcc

C = at tetrahedral void

For SiC

$$10^6 \times 3.2 = \frac{(Z_{\text{eff}}) \left( \frac{28 + 12}{6.023 \times 10^{23}} \right)}{a^3}$$

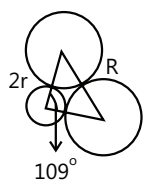
$$Z_{\text{eff}} = 4$$

$$a = 436.23 \text{ pm}$$

For diamond

$$10^6 \times 3.6 = \frac{8 \times \left( \frac{12}{6.023 \times 10^{23}} \right)}{a^3}$$

$$b = 353.76 \text{ pm}$$



$$\frac{R}{\sin 109^\circ} = \frac{2r_c}{\sin\left(\frac{180-109}{2}\right)}$$

$$R = 3.256 r_c$$

$$2R = \sqrt{2} b$$

$$r_c = 76.81 \text{ pm}$$

Analysis by ratio of densities

$$\frac{d_1}{d_2} = \frac{3.2}{3.6} = \frac{M_{\text{SiC}}/V}{M_{\text{C}_2}/V}$$

$$\frac{8}{9} = \frac{(2r_c)^3}{(r_{\text{Si}} + r_c)^3} \times \frac{(28+12)}{24}$$

$$\frac{r_{\text{Si}}}{r_c} = 1.46$$

$$r_{\text{Si}} = 1.12 \text{ \AA}$$

**Sol 19: (C)**

(A) It will change density

(B) Changes always

(C) It will not change as the mass & the volume both are constant.

(D) Decreasing temperature  $\longrightarrow$  Decreases distance  $\longrightarrow$  increases density

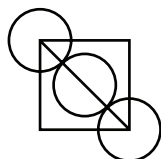
$$\text{Sol 20: (C) Density} = \frac{2 \times (\text{Atomic mass})}{\text{Volume}}$$

$$3.2 \times 10^6 = \frac{Z \times \left(\frac{40}{6.023 \times 10^{23}}\right)}{(4.37 \times 10^{-10})^3}$$

$$Z \sim 4$$

FCC unit

**Sol 21: (D)** Face



$$4r = \sqrt{2} (437 \text{ pm})$$

$$r = 154.5 \text{ pm}$$

Distance between nearest neighbour = 309 pm

**Match the Columns**

**Sol 22:** (A  $\rightarrow$  r, s; B  $\rightarrow$  p, q, r, s; C  $\rightarrow$  q)

(A) Rock salt structure

Co-ordination number = 6

$$A = 2(r_+ + r_-)$$

Co-ordination number of cation and anions are same

$$\text{Distance between nearest anion} = \frac{\sqrt{2}a}{2} = \frac{a}{\sqrt{2}}$$

(B) Zinc blende structure

Co-ordination number of cation = 4

$$\frac{\sqrt{3}a}{4} = r_+ + r_-$$

Co-ordination number of cation and anions are same

(C) Fluorite structure

(p) Incorrect

(q) Correct

(r) Incorrect

(s) Incorrect

**Sol 23:** A  $\rightarrow$  p; B  $\rightarrow$  q, s; C  $\rightarrow$  r

Solve matrix reverse

$$(p) \text{ Shortest distance} = (r_+ + r_-) = \frac{\sqrt{3}a}{2}$$

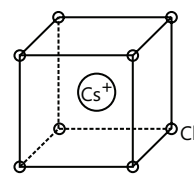
$$(q) = \text{Shortest distance between two cations} = \frac{a}{\sqrt{2}}$$

$$(r) 0.433a = 2r$$

$$(s) = \frac{\sqrt{2}a}{2} = 0.707 a$$

## Previous Years' Questions

**Sol 1: (A, C, D)** The unit cell of CsCl has bcc arrangement of ions in which each ion has eight oppositely charged ions around it in the nearest neighbours as shown below



Unit cell of CsCl

(B) In bcc, coordination number of atom is 8.

(C) In a unit cell, a corner is shared in eight unit cells and a face centre is shared between two adjacent unit cells.

(D) In NaCl unit cell;  $2(r_{\text{Na}^+} + r_{\text{Cl}^-}) = a$   
 $\Rightarrow a = 2(95 + 181) = 552 \text{ pm}$

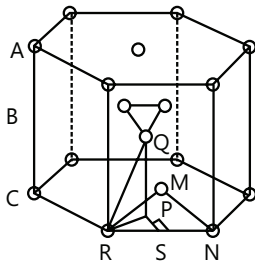
**Sol 2: (B, C) (A) Incorrect statement.** A small difference in sizes of cation and anion favour Schottky defect while Frenkel defect is favoured by large difference in sizes of cation and anion.

**(B) Correct statement.** In Frenkel defect, the smaller atom or ion gets dislocated from its normal lattice positions and occupies the interstitial space.

**(C) In F-centre defect,** some anions leave the lattice and the vacant sites hold the electrons trapped in it maintaining the overall electro-neutrality of solid.

**(D) Incorrect Statement.** In Schottky defect, some of the atoms or ions remaining absent from their normal lattice points without distorting the original unit cell dimension. This lowers the density of solid.

**Sol 3: (B)**



An hcp unit cell

Contribution of atoms from corner =  $\frac{1}{6}$

Contribution from face centre =  $\frac{1}{2}$

$\Rightarrow$  Total number of atoms per unit cell

$$= 12 \times \frac{1}{6} + 2 \times \frac{1}{2} + 3 = 6$$

**Sol 4: (A)** In close packed arrangement, side of the base =  $2r$

$\Rightarrow RS = r$

Also MNR is equilateral triangle,  $\angle PRS = 30^\circ$

In triangle PRS,  $\cos 30^\circ = \frac{RS}{PR} = \frac{\sqrt{3}}{2}$

$$\Rightarrow PR = \frac{2}{\sqrt{3}}RS = \frac{2}{\sqrt{3}}r$$

In right angle triangle PQR,

$$PQ = \sqrt{QR^2 - PR^2} \\ = 2\sqrt{\frac{2}{3}}r$$

$\Rightarrow$  Height of hexagon =  $2PQ = 4\sqrt{\frac{2}{3}}r$

$\Rightarrow$  Volume = Area of base  $\times$  height

$$= 6 \frac{\sqrt{3}}{4} (2r)^2 \times 4\sqrt{\frac{2}{3}}r = 24\sqrt{2}r^3$$

**Sol 5: (D) Packing fraction**

$$= \frac{\text{Volume occupied by atoms}}{\text{Volume of unit cell}}$$

$$= 6 \times \frac{4}{3} \pi r^3 \times \frac{1}{24\sqrt{2}r^3} = 0.74$$

$\Rightarrow$  Fraction of empty space

$$= 1 - 0.74 = 0.26 = 26\%$$

**Sol 6: (A  $\rightarrow$  p,s; B  $\rightarrow$  p,q)** (A) Simple cubic and face centred cubic both have cell parameters  $a = b = c$  and  $\alpha = \beta = \gamma = 90^\circ$ . Also both of them belongs to same, cubic, crystal system.

(B) Both cubic and rhombohedral crystal systems have their cell parameters  $a = b = c$  and  $\alpha = \beta = \gamma$  but they belongs to different crystal systems.

(C) Cubic and tetragonal are two different type of crystal systems having different cell parameters.

(D) Hexagonal and monoclinic are two different crystal systems and both have two of their crystallographic angle of  $90^\circ$ .

**Sol 7:** Ag crystallises in FCC unit cell with 4 atoms per unit cell.

$$\rho = \frac{4 \times 108}{6.023 \times 10^{23} \times a^3} = 10.5 \text{ g cm}^{-3}$$

$\Rightarrow a^3$  (Volume of unit cell)

$$= 6.83 \times 10^{-23} \text{ cm}^3$$

$\Rightarrow a = 4 \times 10^{-8} \text{ cm} = 4 \times 10^{-10} \text{ m}$

$\Rightarrow$  Surface area of unit cell

$$= a^2 = 1.6 \times 10^{-19} \text{ m}^2$$

$\Rightarrow$  Number of unit cells on  $10^{-12} \text{ m}^2$  surface

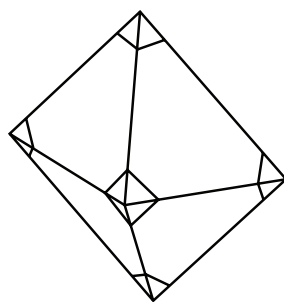
$$= \frac{10^{-12}}{1.6 \times 10^{-19}} = 6.25 \times 10^6$$

∴ There are two atoms (effectively) on one face of unit cell

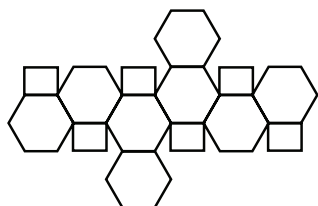
Number of atoms on  $10^{-12} \text{ m}^2$  surface =  $2 \times$  number of unit cell =  $1.25 \times 10^7$ .

$$\Rightarrow x = 7$$

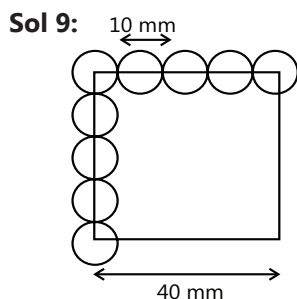
**Sol 8:** The truncated octahedron is the 14-faced Archimedean solid, with 14 total faces : 6 squares and 8 regular hexagons. The truncated octahedron is formed by removing the six right square pyramids one from each point of a regular octahedron as :



Truncated octahedron



Truncated octahedron unfolded in two dimension



(a) Side of square = 40 mm

Distance of marble = 10 mm

Number of marbles spheres along an edge of square with their centres within the square = 5 (shown in diagram)

Maximum number of marbles per unit are =  $5 \times 5 = 25$

(b) If  $x$  mm is the side of square and  $d$  is diameter of marble then maximum number of marbles on square are with centres within square area can be known by the following general formula :

$$N = \left( \frac{x}{d} + 1 \right)^2$$

**Sol 10:** (a) In rock-salt like crystal AB, there are four AB units per unit cell. Therefore, density ( $d$ ) is

$$d = \frac{4 \times 6.023y}{6.023 \times 10^{23} \times 8y \times 10^{-27}}$$

$$[\because a = 2y^{1/3} \text{ mm} = 2y^{1/3} \times 10^{-9} \text{ m}]$$

$$= 5 \times 10^3 \text{ g/m}^3 = 5 \text{ kg/m}^3$$

(b) Since, observed density is greater than expected, theoretical density, there must be some excess metal occupying interstitial spaces. This type of defect is known as metal excess defect.

**Sol 11:** In a cubic crystal system, there are two types of voids known as octahedral and tetrahedral voids. If  $r_1$  is the radius of void and  $r_2$  is the radius of atom creating these voids then

$$\left( \frac{r_1}{r_2} \right)_{\text{octa}} = 0.414 \quad \text{and} \quad \left( \frac{r_1}{r_2} \right)_{\text{tetra}} = 0.225$$

The above radius ratio values indicate that octahedral void has larger radius hence for maximum diameter of atom to be present in interstitial space:

$$r_1 = 0.414 r_2$$

Also in fcc,

$$4r_2 = \sqrt{2} a$$

⇒ Diameter required

$$\begin{aligned} (2r_1) &= (2r_2) \times 0.414 = \frac{a}{\sqrt{2}} \times 0.414 \\ &= \frac{400 \times 0.414}{\sqrt{2}} = 117 \text{ pm} \end{aligned}$$

**Sol 12:** From the given information, the number of atoms per unit cell and therefore, type of unit cell can be known as

$$\begin{aligned} \rho &= \frac{NM}{N_A a^3} \Rightarrow N = \frac{\rho N_A a^3}{M} \\ &= \frac{2 \times 6 \times 10^{23} \times (5 \times 10^{-8} \text{ cm})^3}{75} = 2 \text{ (bcc)} \end{aligned}$$

⇒ In bcc,

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

$$\Rightarrow r = \frac{\sqrt{3}}{4}a$$

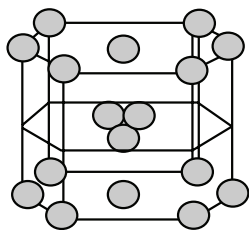
$$= \frac{\sqrt{3}}{4}5 \times 10^{-10} \text{ m}$$

$$= 2.17 \times 10^{-10} \text{ m} = 217 \text{ pm}$$

**Sol 13:** A  $\rightarrow$  p,s; B  $\rightarrow$  p,q; C  $\rightarrow$  q; D  $\rightarrow$  q,r

Crystals class	Axial distances	Angles
Cubic	$a = b = c$	$\alpha = \beta = \gamma = 90^\circ$
Tetragonal	$a = b \neq c$	$\alpha = \beta = \gamma = 90^\circ$
Orthorhombic	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90^\circ$
Hexagonal	$a = b \neq c$	$\alpha = \beta = 90^\circ$ $\gamma = 120^\circ$
Trigonal and rhombohedral	$a = b = c$	$\alpha = \beta = \gamma \neq 90^\circ$
Monoclinic	$a \neq b \neq c$	$\alpha = \beta = 90^\circ$ $\gamma \neq 90^\circ$
Triclinic	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90^\circ$

**Sol 14: (B)**



$$\text{Total effective number of atoms} = 12 \times \frac{1}{6} + 2 \times \frac{1}{2} + 3 = 6$$

**Sol 15: (A)** Height of unit cell  $= 4r\sqrt{\frac{2}{3}}$

$$\text{Base area} = 6 \times \frac{\sqrt{3}}{4} (2r)^2$$

$$\text{Volume} = \text{height} \times \text{base area} = 24\sqrt{2}r^3$$

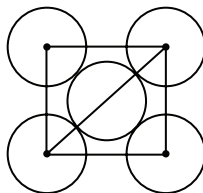
**Sol 16: (D)** Packing fraction = 74%

Empty space = 26%

**Sol 17: (B, C)** Conceptual Fact.

**Sol 18:** Coordination number of Al is 6. It exists in ccp lattice with 6 coordinate layer structure.

**Sol 19: (D)**



$$a = (2\sqrt{2}r)$$

$$\text{Packing Efficiency} = \frac{2 \times \pi r^2}{(2\sqrt{2}r)^2} = \frac{2\pi r^2}{8r^2} = \frac{\pi}{4}$$

**Sol 20: (B)**  $X = 8 \times \frac{1}{8} \times 6 \times \frac{1}{2} = 4$

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

So, unit cell formula of the compound is  $M_2X_4$  and the empirical formula of the compound is  $MX_2$

**Sol 21: (A)** According to the given  $A^+$  is present in the octahedral void of  $X^-$ . The limiting radius in octahedral void is related to the radius of sphere as

$$r_{\text{void}} = 0.414r_{\text{sphere}}$$

$$r_{A^+} = 0.414r_{X^-} = 0.414 \times 250 \text{ pm} = 103.5 = 104 \text{ pm}$$

**Sol 22: (A)** In ccp lattice:

Number of O atoms  $\rightarrow 4$

Number of Octahedral voids  $\rightarrow 4$

Number of tetrahedral voids  $\rightarrow 4$

Number of  $Al^{3+} = 4 \times m$

Number of  $Mg^{2+} = 8 \times m$

Due to charge neutrality

$$4(-2) + 4m(+3) + 8n(+2) = 0$$

$$\therefore m = \frac{1}{2} \text{ and } n = \frac{1}{8}$$

**Sol 23: (B, C, D)** Conceptual facts.