

SOLID STATE

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NEET SYLLABUS

Solid State : Classification of solids based on different binding forces; molecular, ionic covalent and metallic solids, amorphous and crystalline solids (elementary idea), unit cell in two dimensional and three dimensional lattices, calculation of density of unit cell, packing in solids, packing efficiency, voids, number of atoms per unit cell in a cubic unit cell, point defects, (electrical and magnetic properties, Band theory of metals, conductors, semiconductors and insulators.) (Explained in Physics)

OBJECTIVES

After studying this unit, we will be able to :

- *describe general characteristics of solids.*
- *distinction between amorphous and crystalline solids.*
- *study crystal lattice and unit cell.*
- *correlate the density of a substance with its unit cell properties.*
- *explain close packing of particles.*
- *study type of voids and ionic crystals.*
- *describe the imperfections in solids and their effect on properties.*

*"Chemistry without knowledge of solids ; would be a sword without a handle ;
a light without brilliance ; a bell without sound"*

Alwin Mittasch

SOLID STATE

1.0 INTRODUCTION

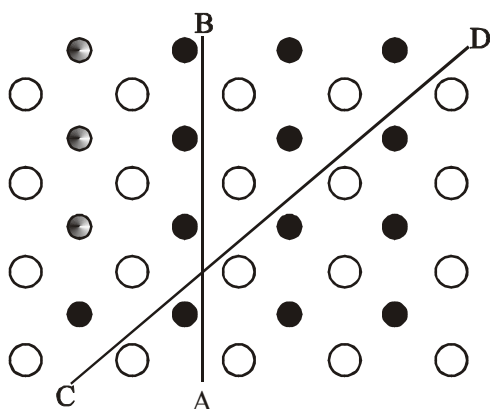
The solid are characterised by incompressibility, rigidity and mechanical strength. The molecules, atoms or ions in solids are closely packed means they are held together by strong forces and can not move randomly. Thus solids have definite volume, shape, slow diffusion, low vapour pressure and possesses the unique property of being rigid. Such solids are known as **true solids** like NaCl, KCl, Sugar, Ag, Cu etc. On the other hand the solid which loses shapes on long standing, flows under its own weight and easily distorted by even mild distortion forces are called **pseudo solids** such as glass, pitch etc.

Some solids such as NaCl, Sugar, Sulphur etc. have properties not only of rigidity and incompressibility but also of having typical geometrical forms. These solids are called as **crystalline solids**. In such solids there is definite arrangements of particles (atoms, ions or molecules) throughout the entire three dimensional network of a crystal in long-range order. This three dimensional arrangement is called **crystal lattice or space lattice**. Other solids such as glass, rubber, plastics etc. have rigidity and incompressibility to a certain extent but they do not have definite geometrical forms or do not have long range order are known as **amorphous solids**.

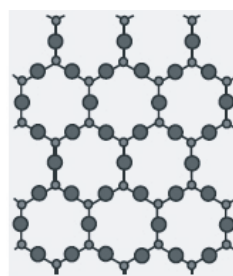
Distinction between Crystalline and Amorphous Solids

Property	Crystalline solids	Amorphous solids
Shape	Definite characteristic geometrical shape	Irregular shape
Melting point	Melt at a sharp and characteristic temperature	Gradually soften over a range of temperature
Cleavage property	When cut with a sharp edged tool, they split into two pieces and the newly generated surfaces are plain and smooth	When cut with a sharp edged tool, they cut into two pieces with irregular surfaces
Heat of fusion	They have a definite and characteristic heat of fusion	They do not have definite heat of fusion
Anisotropic nature	Anisotropic in nature (direction dependent) True solids	Isotropic in nature (direction independent) Pseudo solids or super cooled liquids
Arrangement of particles	Long range order	Only short range order.
Examples	NaCl, Metals, Diamond	Rubber, Plastics

GOLDEN KEY POINTS



Anisotropy in crystals is due to different arrangement of particles along different directions.



(a)



(b)

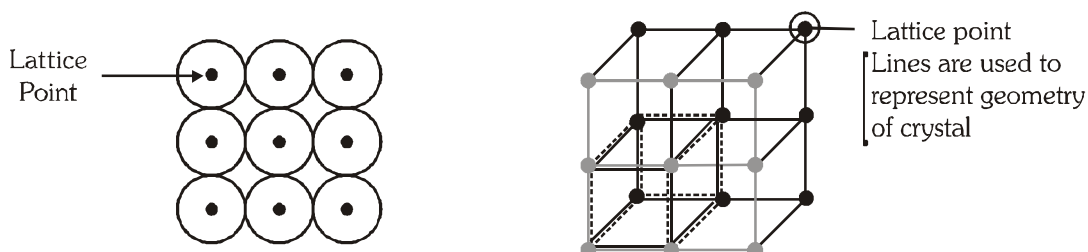
Two dimensional structure of
(a) quartz and (b) quartz glass

Table (a) : Classification of crystalline solids

S. No.	Type of Solid	Constituent Particles	Bonding/ Attractive Forces	Examples	Physical Nature	Electrical Conductivity	Melting Point
1.	Molecular solids (i) Non polar	Molecules	Dispersion or London forces	Ar, CCl ₄ , H ₂ , I ₂ , CO ₂	Soft	Insulator	Very low
	(ii) Polar		Dipole-dipole interactions	HCl, SO ₂	Soft	Insulator	Low
	(iii) Hydrogen bonded		Hydrogen bonding	H ₂ O (ice)	Hard	Insulator	Low
2.	Ionic solids	Ions	Coulombic or electrostatic	NaCl, MgO, ZnS, CaF ₂	Hard but brittle	Insulators in solid state but conductors in molten and in aqueous state	High
3.	Metallic solids	Positive metal ions in a sea of delocalised e ⁻	Metallic bonding	Fe, Cu, Ag, Mg	Hard but malleable and ductile	Conductors in solid and in molten state	Fairly high
4.	Covalent or network solids	Atoms	Covalent bonds	SiO ₂ , SiC, AlN, C(diamond), C(graphite)	Hard Soft	Insulators Conductor	Very high

1.1 Space Lattice/Crystalline Lattice/3-D Lattice

- Space lattice is a regular arrangement of lattice points (atoms or ions or molecules) showing how the particles are arranged at different sites in 3D-view.



- "The three dimensional distribution of component particles in a crystal can be found by X-ray diffraction of different faces of the crystal.
- On the basis of the classification of symmetry, the crystals have been divided into seven systems. These seven systems with the characteristics of their axes (Interfacial angles and intercepts) where some examples of each are given in the following table (b). These crystal systems differ in length of unit cell edges (a, b and c) and the angles between the unit cell edges. In cubic and trigonal (rhombohedral) systems, the three unit edges are of equal lengths but for the rest five systems it is not so. The interfacial angles are all 90° in the cubic, tetragonal and orthorhombic systems but it is not so for the rest four systems.

1.2 Unit Cell (U.C.)

Unit cell of the crystalline substance is defined as the smallest repeating portion which shows the complete geometry of the crystalline substance like brick in wall. A unit cell is the smallest portion of the whole crystal. A unit cell is characterized by the edge lengths a, b and c along the three axes of the unit cell and the angles α , β and γ between the pair of edges bc, ca and ab respectively.

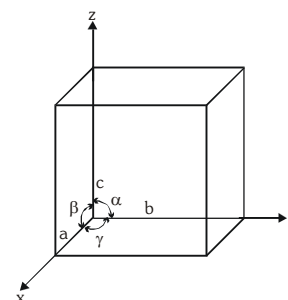
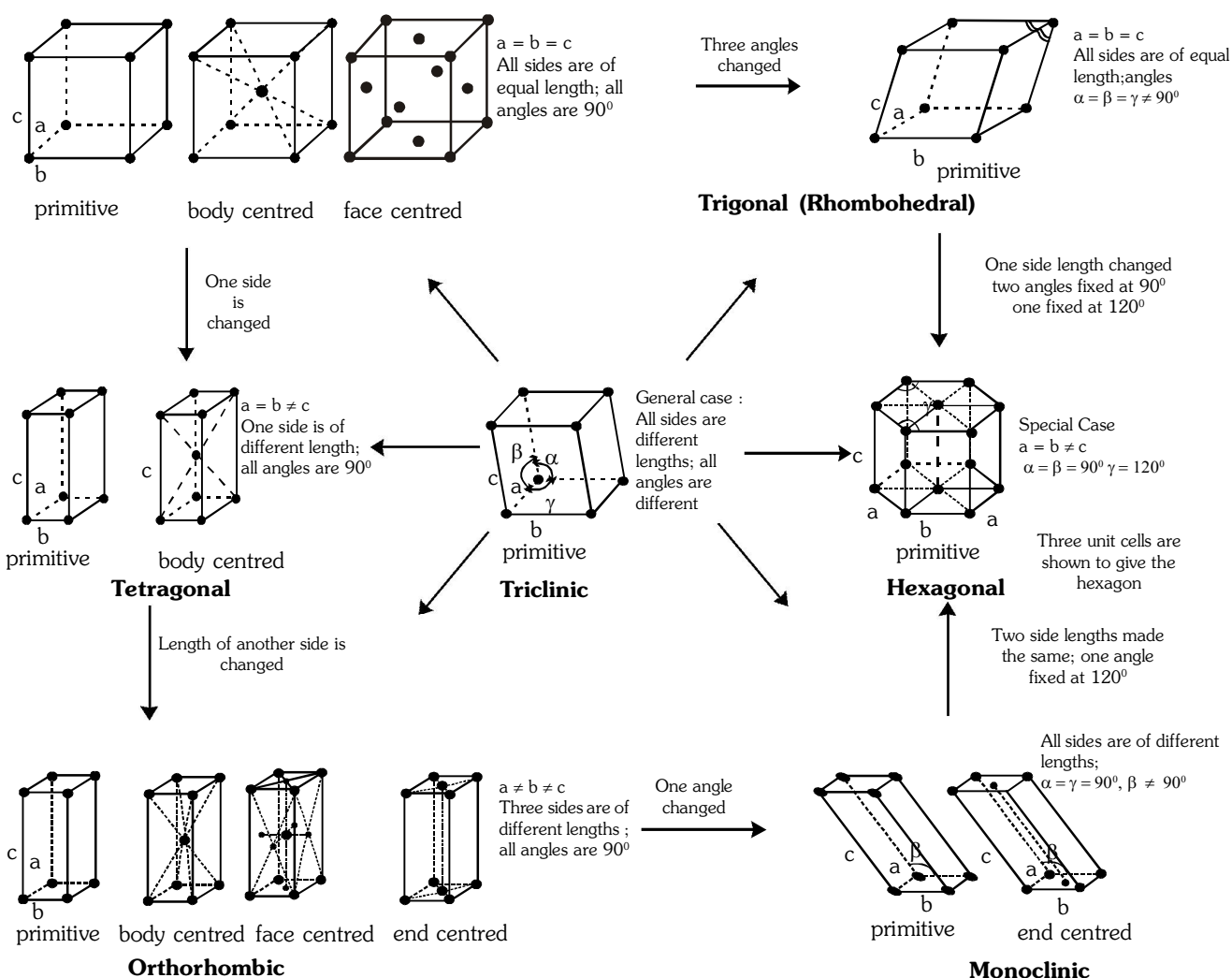


Table (b) : The Seven Crystal Systems (Bravais Lattice)

S. No.	System	Name of Lengths	Edge Angles	Bravais Lattices	Examples
1.	Cubic	$a = b = c$	$\alpha = \beta = \gamma = 90^\circ$	Primitive, Face-centred, Body centred = 3	NaCl, Zinc blende, Cu
2.	Tetragonal	$a = b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	Primitive, Body centred = 2	White tin, SnO_2 , TiO_2 , CaSO_4
3.	Orthorhombic or Rhombic	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	Primitive, Face-centred, Body centred, End centred = 4	Rhombic sulphur, KNO_3 , BaSO_4 Match Box, Duster
4.	Rhombohedral or Trigonal	$a = b = c$	$\alpha = \beta = \gamma \neq 90^\circ$	Primitive = 1	Calcite (CaCO_3), HgS (cinnabar)
5.	Hexagonal	$a = b \neq c$	$\alpha = \beta = 90^\circ, \gamma = 120^\circ$	Primitive = 1	Graphite, ZnO, CdS
6.	Monoclinic	$a \neq b \neq c$	$\alpha = \gamma = 90^\circ, \beta \neq 90^\circ$	Primitive, End centred = 2	Monoclinic sulphur, $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$
7.	Triclinic	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90^\circ$	Primitive = 1	$\text{K}_2\text{Cr}_2\text{O}_7$, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, H_3BO_3
				Total = 14	



1.3 Co-ordination Number

The number of nearest neighbouring particles around a specific particle in a given crystalline substance is called as co-ordination number of that crystalline substance.

1.4 Packing Efficiency or Packing fraction (P.E.)

"Packing efficiency is defined as the ratio of volume occupied by the atoms to the total volume of the crystalline substance"

$$\text{P.E.} = \frac{\text{Volume occupied by atoms present in a crystal}}{\text{Volume of crystal}}$$

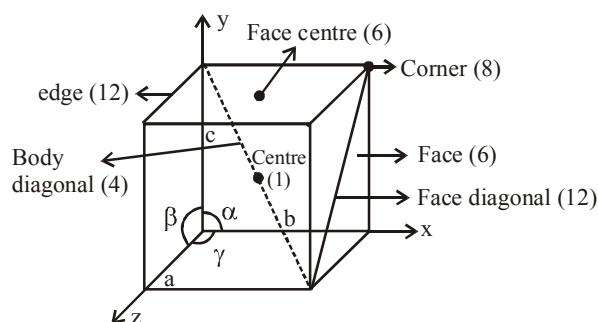
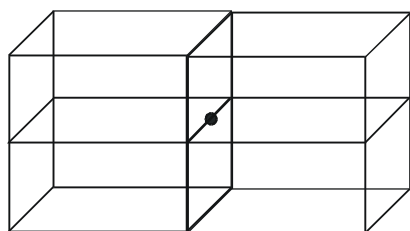
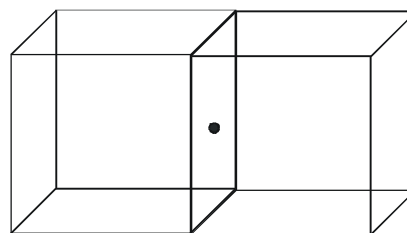
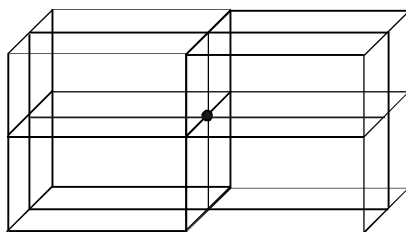
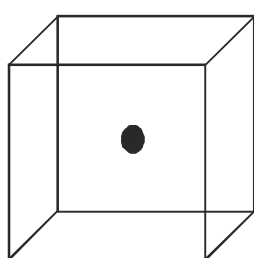
$$\text{P.E.} = \frac{\text{Volume occupied by atoms present in unit cell}}{\text{Volume of unit cell}} \quad \text{or} \quad \text{P.E.} = \frac{z \times (4/3)\pi r^3}{V}$$

Where z = number of atoms present in unit cell / Number of formula units for ionic crystals.

GOLDEN KEY POINTS

● In a cube

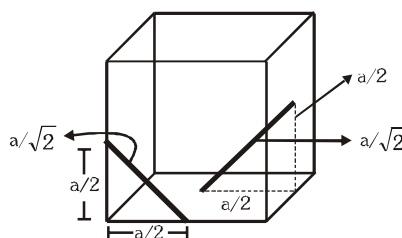
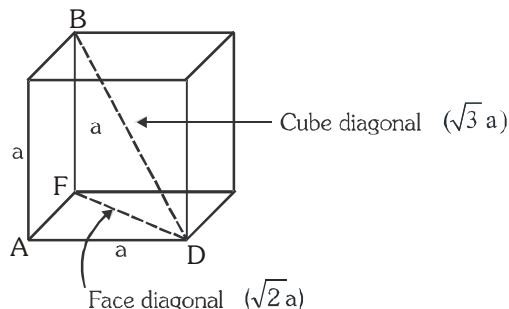
- | | |
|---------------------------------|----------------------------------|
| 1. Number of corners = 8 | 2. Number of faces = 6 |
| 3. Number of edges = 12 | 4. Number of body centre = 1 |
| 5. Number of body diagonals = 4 | 6. Number of face diagonals = 12 |



Contribution of an atom at different lattice points of cube :

- A corner of a cube is common in 8 cubes. So $\frac{1}{8}$ th part of an atom is present at this corner of cube.
- A face of a cube is common in 2 cubes. So $\frac{1}{2}$ th part of an atom is present at the face of a cube.
- An edge of a cube is common in four cubes, so $\frac{1}{4}$ th part of the atom is present at the edge of a cube.
- A cube centre is not common in any another cube, so one complete atom is present at the cube centre.

1.5 Length of Face Diagonal and Cube Diagonal



$$\text{Distance between 2 adjacent face centres} = \frac{a}{\sqrt{2}} = \frac{a\sqrt{2}}{2}$$

$$\text{Distance between 2 adjacent edge centres} = \frac{a}{\sqrt{2}} = \frac{a\sqrt{2}}{2}$$

Consider the triangle AFD (with the help of pythagororous theorem)

$$FD = \sqrt{AF^2 + AD^2} = \sqrt{a^2 + a^2} = \sqrt{2}a \quad (\text{length of face diagonal.})$$

Consider the triangle $\angle BFD$ (with the help of pythagororous theorem)

$$BD = \sqrt{BF^2 + FD^2} = \sqrt{a^2 + (\sqrt{2}a)^2} = \sqrt{3}a \quad (\text{length of cube diagonal})$$

Illustrations

Illustration 1. Which of the following is a non-crystalline solid ?

- (1) CsCl (2) NaCl (3) CaF_2 (4) Glass

Solution. **Ans. (4)**

Illustration 2. Which of the following statements is incorrect about amorphous solids?

- (1) They are anisotropic
(2) They are rigid and incompressible
(3) They melt over a wide range of temperature
(4) There is no orderly arrangement of particles

Solution **Ans. (1)**

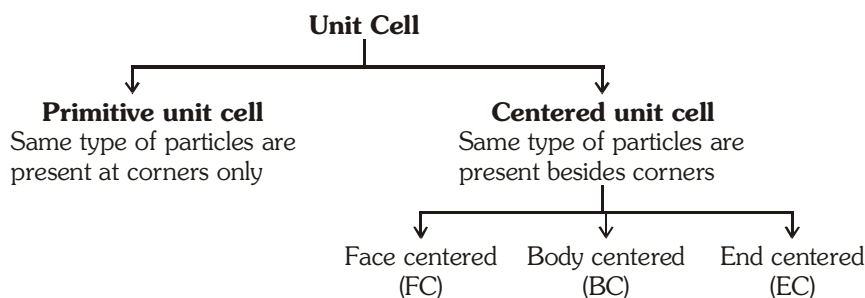
Illustration 3. **Assertion :** Crystalline solids are anisotropic.

Reason : The constituent particles are very closely packed.

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

Solution. **Ans. (2)**

1.6 (I) CLASSIFICATION OF UNIT CELL (As per Bravais)



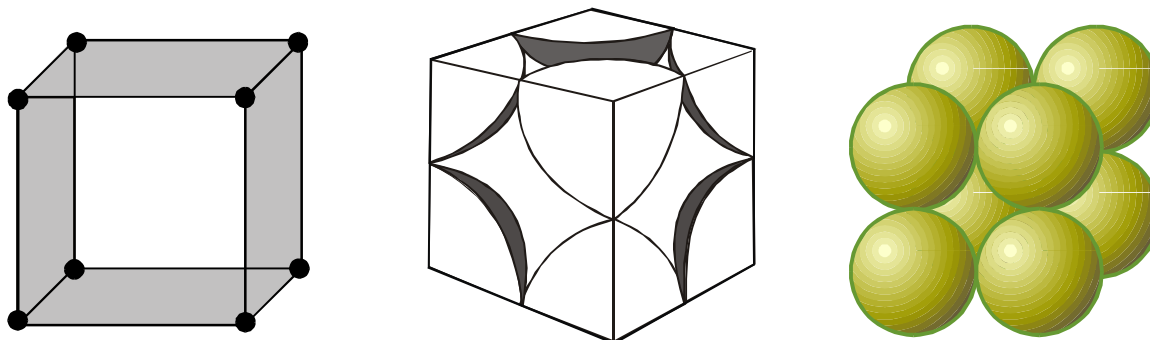
- In end centered same type of particles are present at corners and any two opposite face centres.
- End centered type of Bravais lattice is present only in orthorhombic and monoclinic type unit cell.

(II) TYPES OF CUBIC UNIT CELL

The distance between successive lattice planes of the same type is called the spacing of planes or interplanar distance between the planes. On the basis of this aspect, the lattices may be divided in following classes :

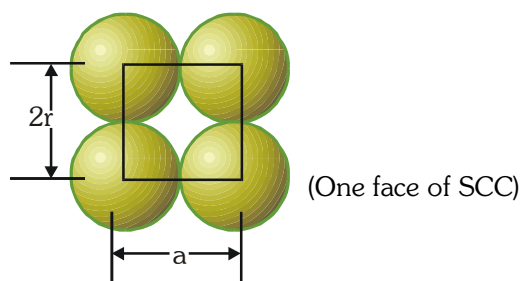
(A) SIMPLE/PRIMITIVE/BASIC CUBIC UNIT CELL

A unit cell having lattice point only at corners is called primitive or simple unit cell. i.e. in this case there is one atom at each of the eight corners of the unit cell considering an atom at one corner as the centre, it will be found that this atom is surrounded by six equidistant neighbours (atoms) and thus the co-ordination number will be six. If 'a' is the side of the unit cell, then the distance between the nearest neighbours shall be equal to 'a'.



(a) **Relationship between edge length 'a' and atomic radius 'r' :** $a = 2r$ i.e.

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



(b) **Number of atoms present in unit cell (z) :** In this case one atom lies at each corner.

Hence simple cubic unit cell contains a total of $\frac{1}{8} \times 8 = 1$ atom / unit cell.

(c) **Packing efficiency (P. E.) :**

$$\text{P.E.} = \frac{\text{Volume occupied by atoms present in unit cell}}{\text{Volume of unit cell}} = \frac{z \times \frac{4}{3} \pi r^3}{V} \left[\because \text{Volume of atom} = \frac{4}{3} \pi r^3 \right]$$

$$\text{For SC : P.E.} = \frac{1 \times \frac{4}{3} \times \pi \times \left(\frac{a}{2}\right)^3}{a^3} = \frac{\pi}{6} = 0.524 \text{ or } 52.4\% \quad \left[\because r = \frac{a}{2} \text{ and } V = a^3, z = 1 \right]$$

In SC, 52.4% of total volume is occupied by atoms

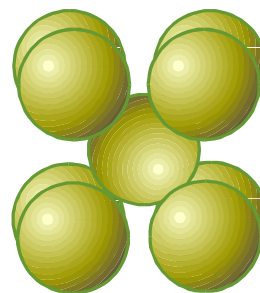
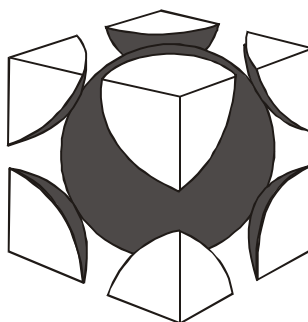
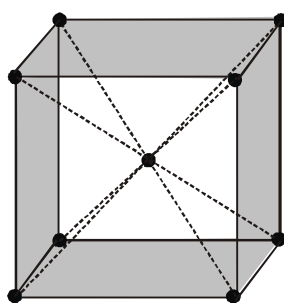
% void space = 47.6

(B) BODY CENTRED CUBIC UNIT CELL (BCC)

A unit cell having lattice point at the body centre in addition to the lattice point at every corner is called as body centered unit cell : where body diagonal particles are touching particle.

Here the central atom is surrounded by eight equidistant atoms and hence the co-ordination number is eight.

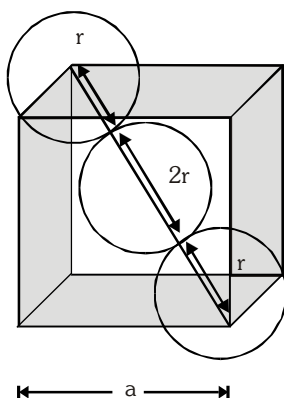
The nearest distance between two atoms will be $\frac{a\sqrt{3}}{2}$



(a) Relationship between edge length 'a' and atomic radius 'r'

In BCC, along cube diagonal all atoms touches each other and the length of cube diagonal is $\sqrt{3}a$.

So, $\sqrt{3}a = 4r$ i.e. $r = \frac{\sqrt{3}a}{4}$



(b) Number of atom present in unit cell (z)

$$z = \left(\frac{1}{8} \times 8\right) + (1 \times 1) = 1 + 1 = 2 \text{ atoms/unit cell}$$

(Corner) (Body centre)

In this case one atom lies at the each corner of the cube.

Thus contribution of the 8 corners is $\left(\frac{1}{8} \times 8\right) = 1$, while that of the body centred is 1 in the unit cell.

Hence total number of atoms per unit cell is $1 + 1 = 2$ atoms

(c) Packing efficiency :

$$\text{P.E.} = \frac{z \times \frac{4}{3} \pi r^3}{V} = \frac{2 \times \frac{4}{3} \times \pi \left(\frac{\sqrt{3}a}{4}\right)^3}{a^3} = \frac{\sqrt{3}\pi}{8} = 0.68 \quad [\because z = 2, r = \frac{\sqrt{3}a}{4}, V = a^3]$$

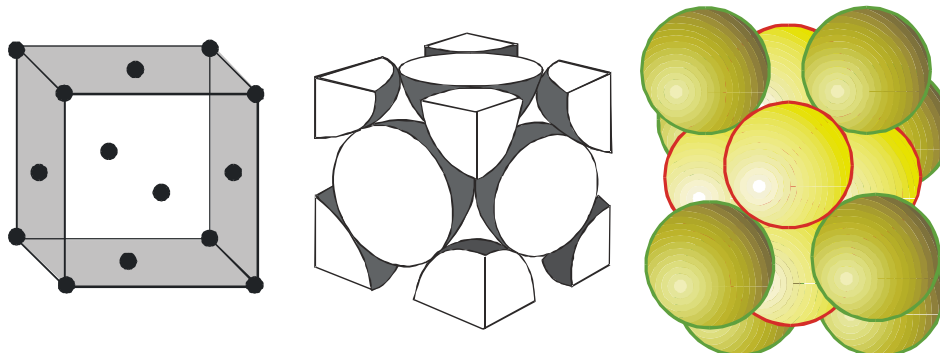
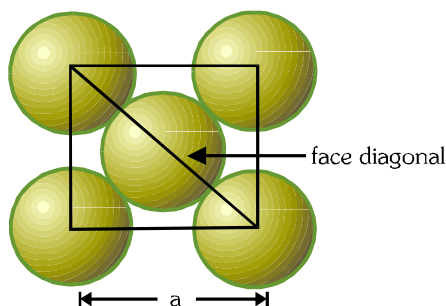
In B.C.C. , 68% of total volume is occupied by atoms.

% void space = 32

(C) FACE CENTRED CUBIC UNIT CELL (FCC)

A unit cell having lattice point at every face centre in addition to the lattice point at every corner called as face centred unit cell. i.e. in this case there are eight atoms at the eight corners of the unit cell and six atoms at the centre of six faces. The co-ordination number will be 12 and the distance between the two

nearest atoms will be $\frac{a\sqrt{2}}{2}$

**(a) Relationship between edge length 'a' and atomic radius 'r' :**

In FCC, along the face diagonal all atoms touches each other and the length of face diagonal is $\sqrt{2}a$.

$$\text{So } 4r = \sqrt{2}a \quad \text{i.e. } r = \frac{\sqrt{2}a}{4} = \frac{a}{2\sqrt{2}} \quad \boxed{r = \frac{a}{2\sqrt{2}}}$$

(b) Number of atoms per unit cell (z) :

$$z = \left(\frac{1}{8} \times 8\right) + \left(6 \times \frac{1}{2}\right) = 1 + 3 = 4 \text{ atoms/unit cell}$$

Corner faces

In this case one atom lies at the each corner of the cube and one atom lies at the centre of each face of the cube. It may noted that only $\frac{1}{2}$ of each face sphere lie within the unit cell and there are six such faces.

The total contribution of 8 corners is $\left(\frac{1}{8} \times 8\right) = 1$, while that of 6 face centred atoms is $\left(\frac{1}{2} \times 6\right) = 3$ in the unit cell. Hence total number of atoms per unit cell is $1 + 3 = 4$ atoms.

(c) Packing efficiency :

$$\text{P.E.} = \frac{z \times \frac{4}{3} \pi r^3}{V} = \frac{4 \times \frac{4}{3} \pi \times \left(\frac{a}{2\sqrt{2}}\right)^3}{a^3} = \frac{\pi}{3\sqrt{2}} = 0.74 \text{ or } 74\% \quad \left[\because z=4, r=\frac{a}{2\sqrt{2}}, V=a^3\right]$$

i.e. In FCC, 74% of total volume is occupied by atoms.

% void space = 26

SUMMARY TABLE

Unit cell	No. of atoms per unit cell	Relation between r & a	Co-ordination Number	Volume occupied by particles (%)
Simple cube	$8 \times \frac{1}{8} = 1$	$r = \frac{a}{2}$	6	$\frac{\pi}{6} \times 100 = 52.4$
Body centred cube (BCC)	$8 \times \frac{1}{8} + 1 = 2$	$r = \frac{a\sqrt{3}}{4}$	8	$\frac{\pi\sqrt{3}}{8} \times 100 = 68$
Face centred cube (FCC)	$8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 4$	$r = \frac{a\sqrt{2}}{4}$	12	$\frac{\pi}{3\sqrt{2}} \times 100 = 74$

Illustrations

Illustration 4. If the radius of an atom of an element is 75 pm and the lattice is body-centred cubic, the edge of the unit cell will be

- (1) 32.475 pm (2) 173.2 pm (3) 37.5 pm (4) 212.1 pm

Solution. **Ans. (2)**

Illustration 5. **Assertion :** A particle present at the corner of the face centred unit cell has 1/8th of its contribution of the unit cell.

Reason : In any space lattice, the corner of the unit cell is always shared by the eight unit cells.

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

Solution. **Ans (3)**

Illustration 6. In a face centred cubic arrangement of A and B atoms where A are present at the corner and B at the face centres, A atoms are missing from 4 corners in each unit cell ? What is the simplest formula of the compound?

Solution. No. of A atoms = $4 \times \frac{1}{8} = \frac{1}{2}$, No. of B atoms = $6 \times \frac{1}{2} = 3$ Formula = $A_{1/2}B_3 = AB_6$

1.7 DENSITY OF THE CRYSTAL (d or ρ)

If the length of edge of the unit cell is known we can calculate the density of the crystal as follow :

Let length of edge of the unit cell be 'a' cm.

∴ Volume of the cubic unit cell = $V \text{ cm}^3 = a^3 \text{ cm}^3$

$$\text{Density of the unit cell} = \frac{\text{Mass of unit cell}}{\text{Volume of unit cell}}$$

Let mass of N particles present in a lattice = m g

$$\text{mass of 1 particles present in a lattice} = \frac{m}{N} \text{ g}$$

$$\text{mass of z particles present in lattice} = \frac{z \times m}{N} \text{ g}$$

$$d = \frac{z \times m}{N \times a^3}$$

where z = number of particles or number of formula units (for ionic crystals)

m = mass of lattice in g

d = density (g/cm^3)

a = edge length in cm

if m = M (molar mass)

then $N = N_A$

$$d = \frac{z \times M}{N_A \times a^3}$$

GOLDEN KEY POINTS

- If number of particles in a lattice = N
number of SC unit cell = N
number of bcc unit cell = $\frac{N}{2}$
number of fcc unit cell = $\frac{N}{4}$
- For calculation use $N_A = 6 \times 10^{23}$
- $1 \text{ pm} = 10^{-12} \text{ m} = 10^{-10} \text{ cm}$
- $1 \text{ \AA} = 10^{-10} \text{ m} = 10^{-8} \text{ cm}$

BEGINNER'S BOX-1

- Aluminium (Molecular weight = 27) crystallises in a cubic unit cell with edge length $a = 100 \text{ pm}$, with density, $d = 180 \text{ g/cm}^3$, then type of unit cell is
(1) SC (2) BCC (3) FCC (4) HCP
- An element has BCC unit cell, with edge length $10 \text{ \AA}$, if density is 0.2 g/cm^3 , then molar mass of the compound is :-
(1) 240 (2) 60 (3) 35 (4) 280
- In a tetragonal crystal :-
(1) $a = b = c$, $\alpha = \beta = \gamma = 90^\circ \neq \gamma$ (2) $\alpha = \beta = \gamma = 90^\circ$, $a = b \neq c$
(3) $\alpha = \beta = \gamma = 90^\circ$, $a \neq b \neq c$ (4) $\alpha = \beta = 90^\circ$, $\gamma = 120^\circ$, $a = b \neq c$
- Edge length of a cube is 400 pm , its body diagonal would be :-
(1) 500 pm (2) 600 pm (3) 566 pm (4) 693 pm
- A metal crystallises into two cubic phases fcc and bcc whose unit lengths are 3.5 and $3.0 \text{ \AA}$ respectively, the ratio of densities of fcc and bcc is :-
(1) 1.26 (2) 1.75 (3) 2.10 (4) 1.90

1.8 CLOSE PACKING OF IDENTICAL SOLID SPHERES

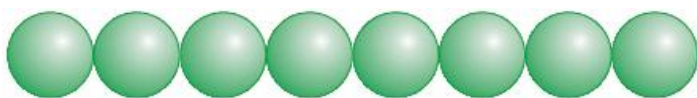
The solids which have non-directional bonding, their structures are determined on the basis of geometrical consideration. For such solids, it is found that the lowest energy structure is that in which each particle is surrounded by the greatest possible number of neighbours. In order to understand the structure of such solids, let us consider the particles as hard sphere of equal size in three directions. Although there are many ways to arrange the hard spheres but the one in which maximum available space is occupied will be economical which is known as closed packing now we describe the different arrangements of spherical particles of equal size.

When the spheres are packed in a plane it gives two types of packing.

Types of Packing :-

(A) Single line arrangement

(1) Close packing of atoms in one dimension

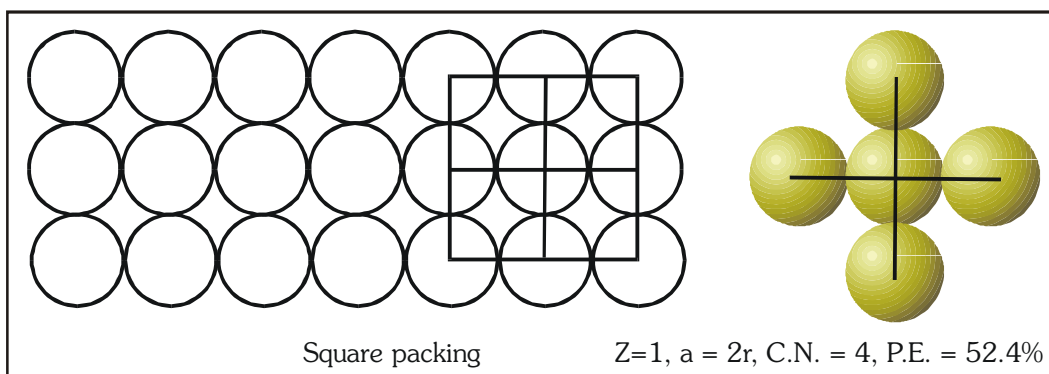


coordination number = 2

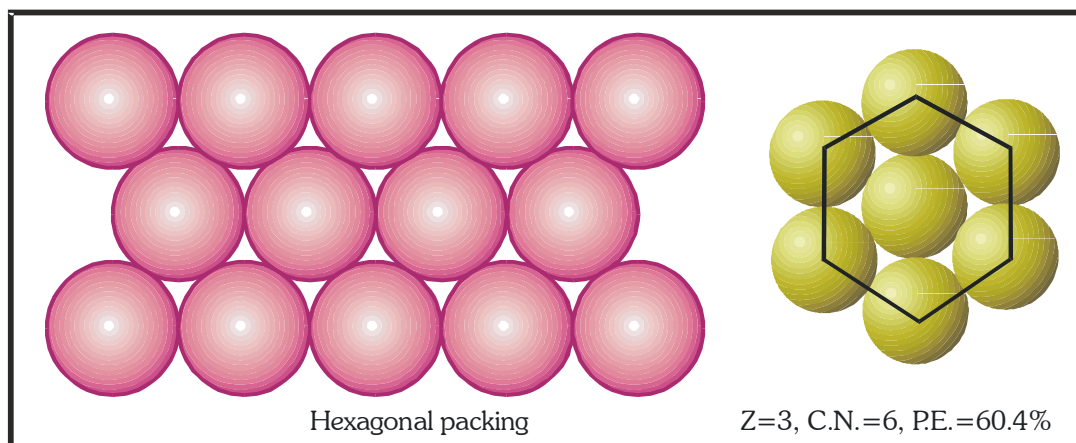
(B) Single layer arrangement

(2) Close packing of atoms in two dimensions :- When the spheres are placed in a plane, it gives two type of packing.

(a) Square close packing :- The centres of the spheres lie one below another. This type of arrangement is called square packing. In such packing one sphere touches four other spheres. In this case 52.4% of the volume is occupied. The remaining 47.6% of the volume is empty and is called void volume.



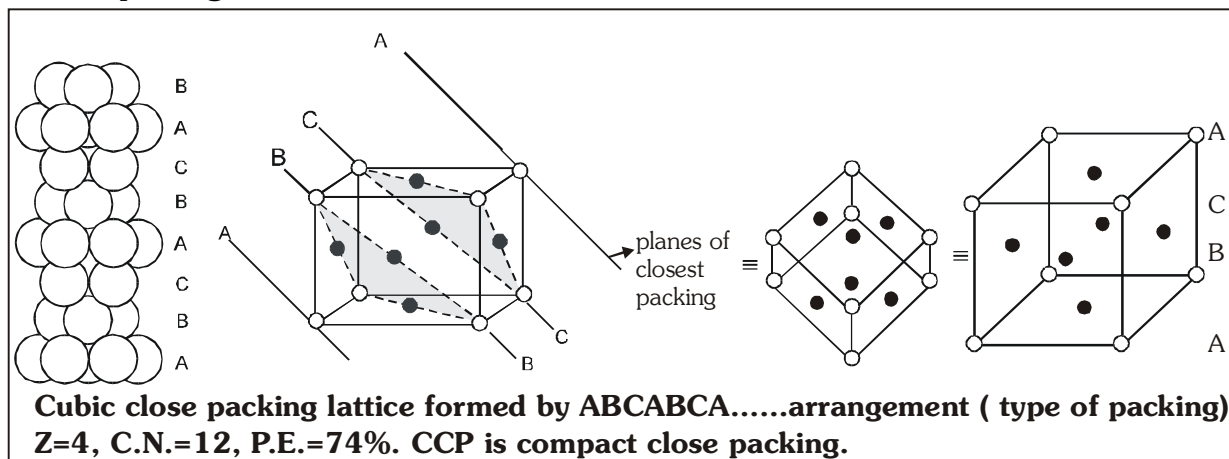
(b) Hexagonal close packing :- Another type of arrangement of atoms is shown below. This type of packing is called hexagonal packing. In such packing one sphere touches six other spheres. In this case 60.4% of the volume is occupied. The remaining 39.6% of the volume is empty and is called void volume. Therefore this type of packing is more compact than the square packing.



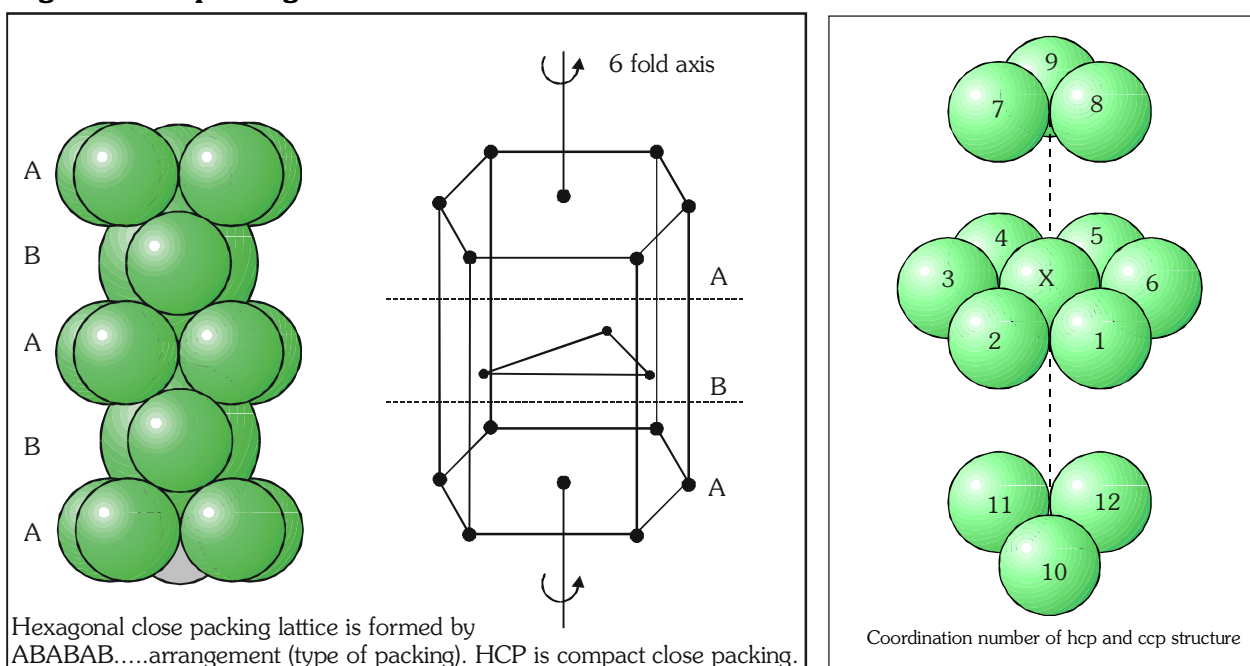
(C) Multi layer arrangement :-

(3) Close packing of atoms in three dimensions

(a) **Simple cubic close packing** (Three dimensional close packing from two dimensional closed packed layers) When first square arrangement of layer A is exactly placed above occupies 2nd square arrangement of layer A and so on. So this type of arrangement is known as **AAA..... arrangement** and its unit cell is simple cubic unit cell.



Hexagonal close packing :-



$$\text{Number of particles in hexagonal unit cell (z)} = 12 \times \frac{1}{6} + 2 \times \frac{1}{2} + 3 \times 1 = 6$$

C.N. = 12, P.E. = 74%, type of packing ABAB.....

GOLDEN KEY POINTS

- Some examples of metals with their lattice types and coordination number are given in the following table.

Li	Be		Body Centre Cubic (bcc)											
Na	Mg	Al	Face Cenral Cubic	Hexagonal Closed Packed (hcp)										
K	Ca	Cs	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn			
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd			
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au				

● MULTILAYER CLOSE PACKING

Contents	SCC	BCC	CCP/FCC	HCP
Type of packing	AAAA... packing but not close packing	ABAB..... packing but not close packing	ABCABC close packing	ABAB close packing
No. of atoms	1	2	4	6
Co-ordination no.	6	8	12	12
Packing efficiency	52.4%	68%	74%	74%
Examples	Po	IA, Ba V & Cr group Fe, Mn	Ca, Sr, Al Co group, Ni group, Copper group, all inert gases except He	Remaining d-block elements Be & Mg

- In close packing, number of particles = N, number of OHV = N, Number of THV = 2N

Illustrations

Illustration 7. The arrangement of the first two layers, one above the other, in HCP and CCP arrangements is
 (1) Exactly same in both cases (2) Partly same and partly different
 (3) Different from each other (4) Nothing definite

Solution. **Ans. (1)**

Illustration 8. **Assertion :** ABAB.... pattern of close packing gives ccp arrangement.
Reason : In FCC arrangement each sphere associated with two tetrahedral voids.
 (1) A (2) B (3) C (4) D

Solution. **Ans. (4)**

Illustration 9. "There is no difference in the arrangement of atoms in CCP and HCP structure" Do you agree with this statement ? Explain why.

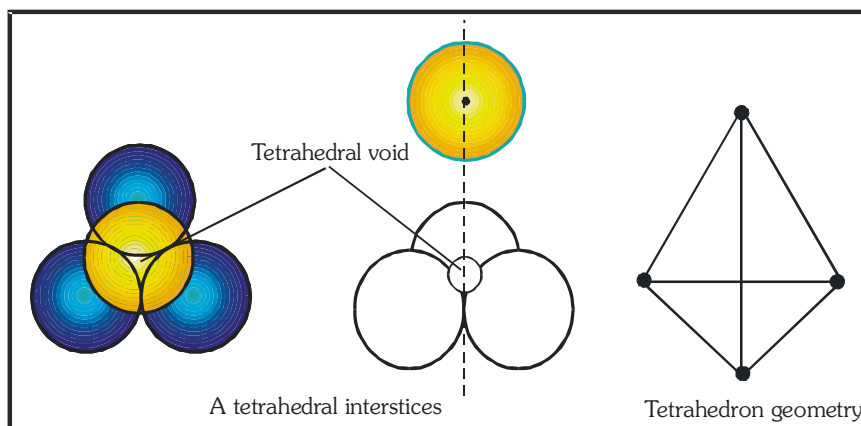
Solution. Statement is incorrect
 CCP ABC ABC ABC
 HCP AB AB AB

1.9 INTERSTICES OR VOIDS OR HOLES IN CRYSTALS

It has been shown that the particles are closely packed in the crystals even though there is some empty space left in between the spheres. This is known as interstices (or interstitial site or hole or empty space or voids). In three dimensional close packing (CCP & HCP) the interstices are of two types : (i) tetrahedral interstices and (ii) octahedral interstices.

(A) Tetrahedral Interstices

We have seen that in hexagonal close packing (HCP) and cubic close packing (CCP) each sphere of second layer touches with three spheres of first layer. Thus they leave a small space in between which is known as **tetrahedral site or interstices** or the vacant space between 4 touching spheres is called as tetrahedral void. Since a sphere touches three spheres in the below layer and three spheres in the above layer hence there are two tetrahedral sites associated with one sphere.



It may be noted that a tetrahedral site does not mean that the site is tetrahedral in geometry but it means that this site is surrounded by four spheres and by joining the centres of these four spheres forms a regular tetrahedron.

In FCC, one corner and its three face centres form a tetrahedral void

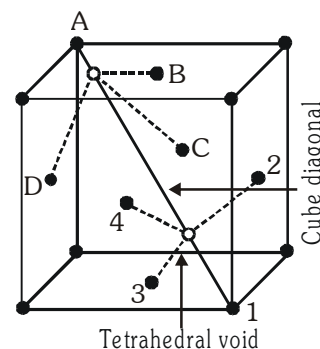
In FCC, two tetrahedral voids are obtained along one cube diagonal.

So in FCC, 8 tetrahedral voids are present.

In FCC, total number of atoms = 4

In FCC, total number of tetrahedral voids = 8

So, we can say that, in 3D close packing 2 tetrahedral voids are attached with one atom.

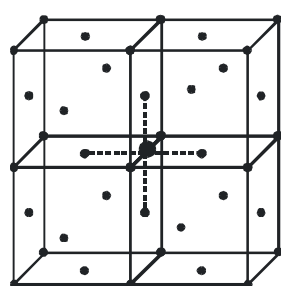
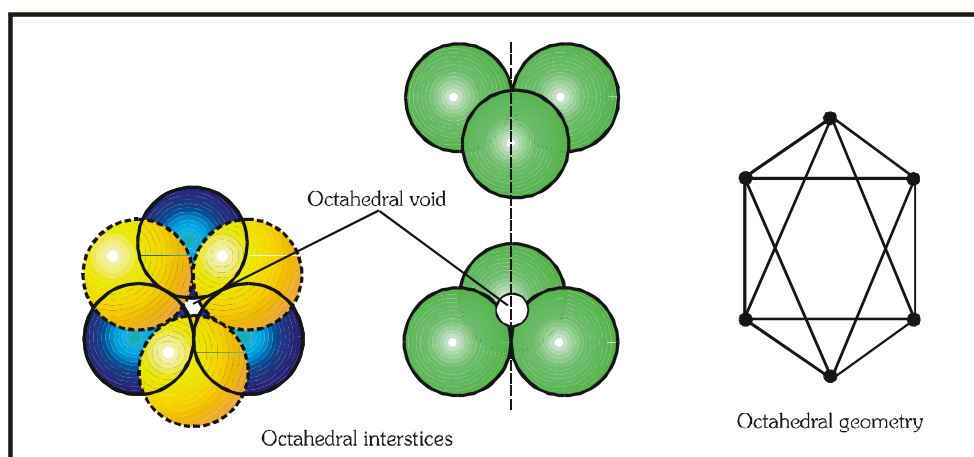


(B) Octahedral Interstices

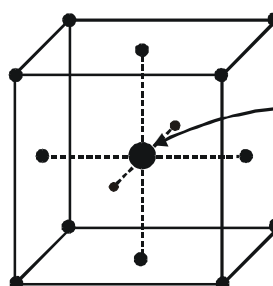
Hexagonal close packing (hcp) and cubic close packing (ccp) also form another type of interstices which is called octahedral site. The vacant space between 6 touching spheres is called as octahedral void.

In the figure, two layers of close packed spheres are shown. The spheres of first layer are shown by full circles while that of second layer by dotted circles. Two triangles are drawn by joining the centres of three touching spheres of both the layers :

In fcc, 6 face centres form a octahedral void. On super imposing these triangles on one another one octahedral site is created. It may be noted that an octahedral site does not mean that the hole is octahedral in shape but it means that this site is surrounded by six nearest neighbour lattice points arranged octahedrally.



Octahedral void (at the edge)
(1/4 th part of octahedral void is obtained at each edge)



Octahedral void (at the body centre)

$$\text{In FCC, total number of octahedral voids} = (1 \times 1) + (12 \times \frac{1}{4}) = 1 + 3 = 4$$

(Cube centre) (edge centre)

In FCC, number of atoms = 4 and number of octahedral voids = 4 : number of tetrahedral voids = 8

So we can say that, in 3D close packing one octahedral void is attached with one atom.

Illustrations

Illustration 10. The number of octahedral sites in a cubical close packed array of N spheres is

- (1) $N/2$ (2) $2N$ (3) N (4) $4N$

Solution. **Ans. (3)**

Illustration 11. Atom A is every element of FCC, atom B is present at every Octahedral void, atom C is present at 25% of Tetrahedral void. Find out the possible molecular formula of the compound ?

Solution. Atom A is every element of FCC = 4 atoms of A
 Atom B is present at every octahedral void = 4 atoms of B

$$\text{Atom C is present at 25\% of tetrahedral void} = 8 \times \frac{25}{100} = 2 \text{ atoms of C}$$

So, the possible molecular formula is $A_4 B_4 C_2 = A_2 B_2 C$.

1.10 STUDY OF IONIC CRYSTALS

Limiting Radius Ratio

An ionic crystal contains a large number of cations and anions. Generally cations are smaller in size than that of anions. The cations are surrounded by anions and they touch each other. These ions are arranged in space in such a way to produce maximum stability.

So the limiting radius ratio tells about :

- (i) Stability of ionic crystal
- (ii) Coordination number
- (iii) Geometry of voids

(a) Triangular : All anions touches each other and co-ordination number is 3

$$\cos \theta = \frac{R}{R+r}$$

$$\cos 30^\circ = \frac{R}{r+R}$$

$$\sqrt{3}R + \sqrt{3}r = 2R$$

$$\sqrt{3}r = (2 - \sqrt{3})R$$

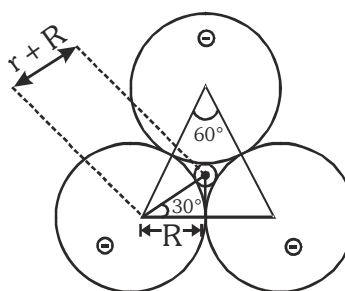
$$\frac{r}{R} = \frac{2 - \sqrt{3}}{\sqrt{3}} = \frac{2 - 1.73}{1.73} = \frac{0.27}{1.73} = 0.155$$

$$\text{L.R.R.} = 0.155 = \frac{r}{R} < 1$$

(b) Tetrahedral void : All anions touches each other and co-ordination number of cation is 4.

$$\text{Face diagonal AC} = \sqrt{2}a = 2R$$

$$R = \frac{a}{\sqrt{2}} \quad \text{or} \quad a = \sqrt{2}R$$



Triangle ACD -

$$AD^2 = AC^2 + CD^2$$

$$AD^2 = (\sqrt{2}a)^2 + (a)^2 = 2a^2 + a^2 = 3a^2$$

$$AD = \sqrt{3} a$$

According to cube diagonal AD

$$\therefore \frac{\sqrt{3}a}{2} = r + R$$

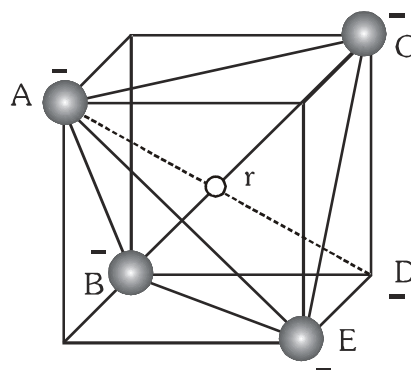
$$\therefore \sqrt{3}a = 2r + 2R = AD$$

Put the value of $a = \sqrt{2}R$

$$\sqrt{3} \times \sqrt{2}R = 2r + 2R$$

$$\frac{\sqrt{3} \times \sqrt{2}R}{2R} = \frac{2r + 2R}{2R} \quad \text{or} \quad \frac{\sqrt{3}}{\sqrt{2}} = \frac{r}{R} + 1$$

$$\frac{r}{R} = \frac{\sqrt{3}}{\sqrt{2}} - 1 = \frac{\sqrt{3} - \sqrt{2}}{\sqrt{2}} = \frac{1.73 - 1.414}{1.414} = 0.225$$



(c) Octahedral void : All the anions are touch each other and co-ordination number is 6.

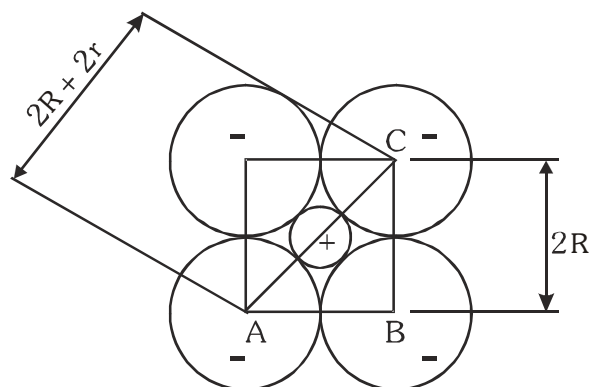
$$\begin{aligned} \text{In } \triangle ABC \quad AC^2 &= AB^2 + BC^2 \\ (2R + 2r)^2 &= (2R)^2 + (2R)^2 \end{aligned}$$

$$(2R + 2r) = \sqrt{8R^2}$$

$$2R + 2r = 2\sqrt{2}R$$

$$2R(\sqrt{2} - 1) = 2r$$

$$\frac{r}{R} = \sqrt{2} - 1 = 0.414$$



(d) Cubic void : All the anions are touch each other and co-ordination number is 8.

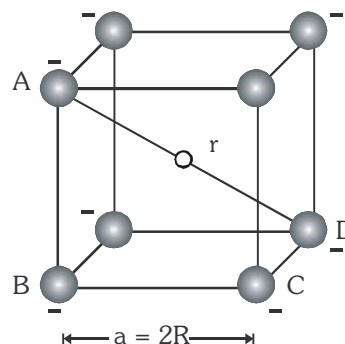
According to cube diagonal

$$AD = \sqrt{3}a = 2r + 2R \quad (a = 2R = BC)$$

$$\sqrt{3} \times 2R = 2r + 2R$$

Dividing by 2r on both sides.

$$\sqrt{3} = \frac{r}{R} + 1 \Rightarrow \frac{r}{R} = \sqrt{3} - 1 = 1.732 - 1 = 0.732$$



GOLDEN KEY POINTS

- The preferred direction of the structure with increase in the radius ratio is as follows :
Plane triangular $\xrightarrow{0.225}$ Tetrahedral $\xrightarrow{0.414}$ octahedral $\xrightarrow{0.732}$ Cubic

- LIMITING RADIUS RATIO FOR VARIOUS TYPES OF VOIDS**

Limiting radius ratio = r/R	Coordination Number	Structural Arrangement (Type of voids)	Example
$0.155 \leq r/R < 0.225$	3	Plane Trigonal	Boron Oxide(B_2O_3)
$0.225 \leq r/R < 0.414$	4	Tetrahedral	ZnS, SiO_2
$0.414 \leq r/R < 0.732$	6	Octahedral	NaCl, MgO
$0.732 \leq r/R < 1.000$	8	Cubical	CsCl

Illustrations

Illustration 12. Assertion : In crystal lattice, the size of the cation is larger in a tetrahedral hole than in an octahedral hole.

Reason : The cations occupy more space than atoms in crystal packing.

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

Solution. Ans. (4)

Illustration 13. Each unit cell of NaCl consists of 14 Cl^- ions and

- (1) 13 Na^+ (2) 14 Na^+ (3) 6 Na^+ (4) All are wrong

Solution. Ans. (1)

Illustration 14. A solid A^+B^- has NaCl type close packed structure. If the anion has a radius of 250 pm, what should be the ideal radius for the cation ? Can a cation C^+ having a radius of 180 pm be slipped into the tetrahedral site of the crystal A^+B^- ? Give reason for your answer.

Solution In Na^+Cl^- crystal each Na^+ ion is surrounded by 6 Cl^- ions and vice versa. Thus Na^+ ion is placed in octahedral hole.

The limiting radius ratio for octahedral site = 0.414 or $\frac{A^+}{B^-} = \frac{r}{R} = 0.414$

Given that radius of anion (B^-) $R = 250$ pm

i.e. radius of cation (A^+) $r = 0.414 R = 0.414 \times 250$ pm = 103.5 pm

Thus ideal radius for cation (A^+) is $r = 103.5$ pm.

We know that (r/R) for tetrahedral hole is 0.225.

$\therefore \frac{r}{R} = 0.225$: So $r = 56.25$ pm

Thus ideal radius for cation is 56.25 pm for tetrahedral hole. But the radius of C^+ is 180 pm. It is much larger than ideal radius i.e. 56.25 pm. Therefore we can not slipped cation C^+ into the tetrahedral site.

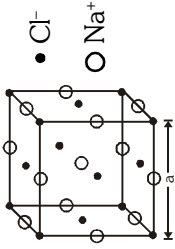
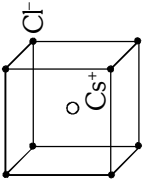
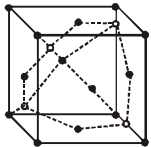
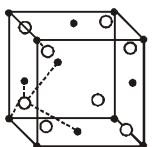
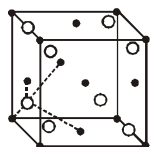
Illustration 15. Assertion :- In rock salt structure, the sodium ions occupy octahedral voids.

Reason :- The radius ratio r^+/r^- in case of NaCl lies between 0.225 to 0.414.

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

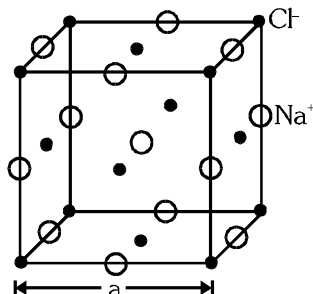
Solution. Ans. (3)

1.11 SOME IONIC CRYSTALS

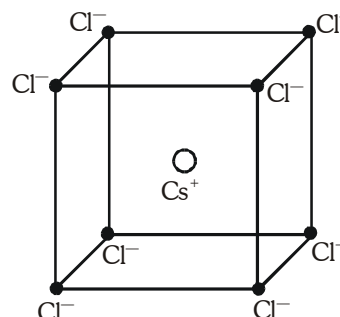
S. No.	Type of Ionic Crystal	Geometry	Co-ordination Number	No. of formula's per U.C.	Examples
1.	NaCl (1 : 1) (Rock Salt Type)	$\begin{matrix} \text{Na}^+ & \rightarrow & \text{At every OHV} \\ \text{C.C.P.} & \swarrow \searrow & \\ \text{Cl}^- & \rightarrow & \text{Every element of C.C.P.} \end{matrix}$	6 : 6	$4\text{Na}^+ + 4\text{Cl}^-$ 4NaCl (4)	Halides of (Li, Na, K, Rb) Oxides and sulphides of alkaline, earth metals (Except BeS) AgCl, AgBr, NH_4X 
2.	CsCl Type (1 : 1)	$\begin{matrix} \text{Cs}^+ & \rightarrow & \text{At body centre of} \\ & & \text{at cubic void} \\ \text{B.C.C.} & \swarrow \searrow & \\ \text{Cl}^- & \rightarrow & \text{At every corner} \end{matrix}$	8 : 8	$1\text{Cs}^+ + 1\text{Cl}^-$ 1CsCl (1)	Halides of 'Cs' TlCl, TlBr, CsS 
3.	ZnS Type (1 : 1) (Zinc Blende Type) (Sphalerite)	$\begin{matrix} \text{Zn}^{+2} & \rightarrow & \text{At 50\% of T.H.V. or} \\ & & \text{at alternate tetrahedral void} \\ \text{C.C.P.} & \swarrow \searrow & \\ \text{S}^{+2} & \rightarrow & \text{Every element of C.C.P.} \end{matrix}$	4 : 4	$4\text{Zn}^{+2} + 4\text{S}^{-2}$ 4ZnS (4)	BeS, BeO, CaO, AgI, CuCl, CuBr, CuI 
4.	CaF ₂ Type (1 : 2) (Fluorite Type)	$\begin{matrix} \text{Ca}^{+2} & \rightarrow & \text{Every element of C.C.P.} \\ \text{C.C.P.} & \swarrow \searrow & \\ \text{F}^- & \rightarrow & \text{At every T.H.V.} \end{matrix}$	$4\text{Ca}^{+2}, 8\text{F}^-$ 8 : 4	$4\text{Ca}^{+2} + 8\text{F}^-$ 4CaF_2 (4)	BaCl ₂ , BaF ₂ SrCl ₂ , SrF ₂ CaCl ₂ , CaF ₂ 
5.	Na ₂ O Type (2 : 1) (Antifluorite)	$\begin{matrix} \text{Na}^+ & \rightarrow & \text{At every T.H.V.} \\ \text{C.C.P.} & \swarrow \searrow & \\ \text{O}^{2-} & \rightarrow & \text{Every element of C.C.P.} \end{matrix}$	$8\text{Na}^+, 4\text{O}^{2-}$ 4 : 8	$8\text{Na}^+ + 4\text{O}^{2-}$ $4\text{Na}_2\text{O}$ (4)	Li ₂ O, Li ₂ S Na ₂ O, Na ₂ S K ₂ O, K ₂ S 
6.	ZnS Type (1 : 1) (Wurtzite) another geometry of ZnS	$\begin{matrix} \text{Zn}^{+2} & \rightarrow & 50\% \text{ of T.H.V. or} \\ & & \text{(at alternate T.H.V.)} \\ \text{H.C.P.} & \swarrow \searrow & \\ \text{S}^{2-} & \rightarrow & \text{Every element of H.C.P.} \end{matrix}$	4 : 4	$6\text{Zn}^{+2} + 6\text{S}^{-2}$ 6ZnS (6)	Same as sphalerite

● **NaCl TYPE****For NaCl :**Distance between two nearest ions ($r^+ + r^-$) :-

$$2r^+ + 2r^- = a \quad \text{i.e.} \quad r^+ + r^- = \frac{a}{2}$$

**CsCl TYPE****For CsCl :**Distance between two nearest ions ($r^+ + r^-$) :-

$$2r^+ + 2r^- = \sqrt{3}a \quad \text{i.e.} \quad r^+ + r^- = \frac{\sqrt{3}}{2}a$$

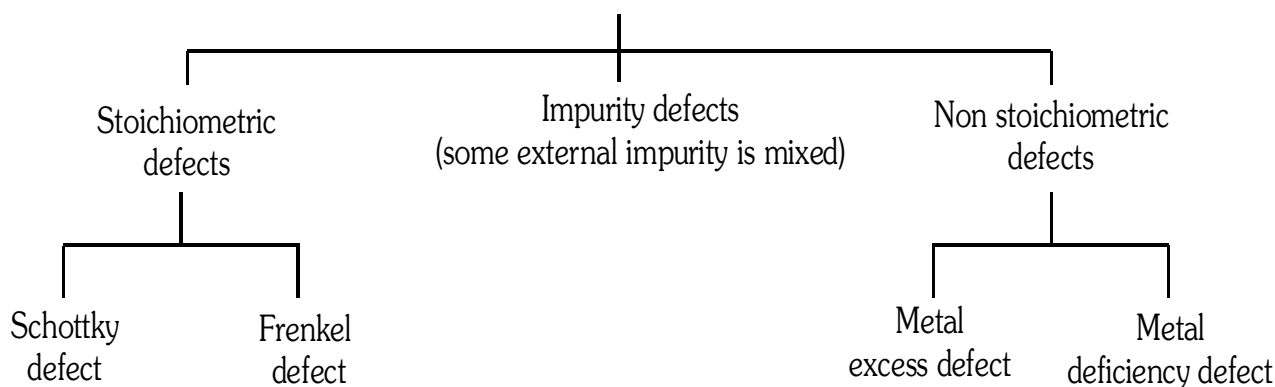


In both structures cation and anion can exchange their position.

1.12 DEFECTS OR IMPERFECTIONS IN SOLIDS

Ideal crystal : The crystal in which all the lattice points are occupied by the component particles or groups of particles is called an ideal crystal. Ideal crystals are grown up at absolute kelvin temperature (zero K).

Solid state is characterised by vibratory motion about the mean position of constituent particles. At absolute zero, all the types of motions cease, and therefore crystals tend to have a perfectly ordered arrangement. As the temperature increases, molecular motions (vibratory amplitudes) increase and therefore the ions may lose their usual sites and either get missed or occupy interstitial positions in the crystal, i.e., deviations from ordered arrangement take place. Any deviation from the perfectly ordered arrangement gives rise to a defect or imperfection in the crystal. Defect in crystals are produced either due to thermal effects or by adding certain impurities in the pure crystals (doping). Defects in crystals may be discussed as

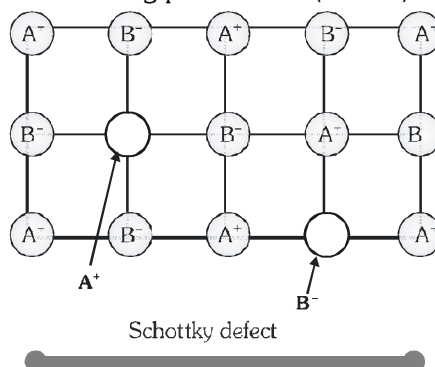
Crystal defects**(A) Stoichiometric Defects**

Stoichiometric compounds are those in which the number of positive and negative ions are exactly in the ratio as shown by their chemical formulae. Two types of defects are observed in these compounds.

(a) Schottky defect,

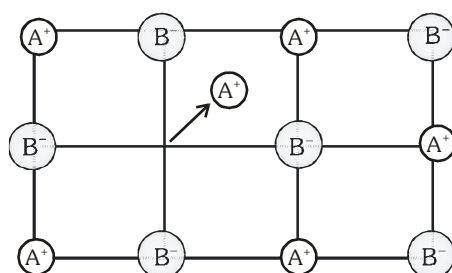
(b) Frenkel defect

- (a) Schottky defect :** This type of defect is produced when equal number of cations and anions are missing from their respective positions leaving behind a pair of holes. The crystal as a whole remains neutral because the number of missing positive ions (cations) and negative ions (anions) is the same



- ### Consequences of schottky defect :

- (b) Frenkel defect :** This type of defect is created when an ion leaves its appropriate site in the lattice and occupies an interstitial site. A hole or vacancy is thus produced in the lattice.



Frenkel defect

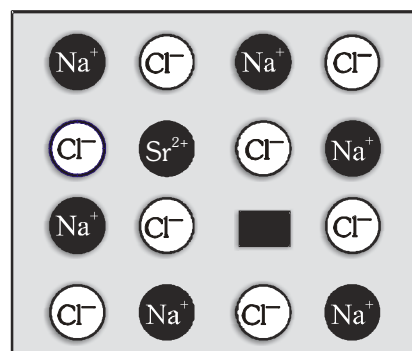
Frenkel defect is exhibited in ionic compounds in which the radius ratio $[r^+/r^-]$ is low. The cations and anions differ much in their sizes and the ions have low co-ordination numbers. Examples are ZnS, AgBr, AgI, AgCl.

Consequences of Frenkel defect :

- It is a kind of dislocation defect.
- The closeness of like charges tends to increase the dielectric constant of the crystal.
- The crystal showing a frenkel defect conducts electricity to a small extent by ionic mechanism.
- The density of the crystal remains the same.

(B) Impurity Defect

If molten NaCl containing a little amount of SrCl_2 is crystallised, some of the sites of Na^+ ions are occupied by Sr^{2+} . Each Sr^{2+} replaces two Na^+ ions. It occupies the site of one ion and the other site remains vacant. The cationic vacancies thus produced are equal in number to that of Sr^{2+} ions. Another similar example is the solid solution of CdCl_2 and AgCl .



Induction of cation vacancy in NaCl by substitution of Na^+ by Sr^{2+}

(C) Non-stoichiometric Defects

These types of defects are observed in the compounds of transitional elements. These defects arise either due to the presence of excess metal ions or excess non-metal ions.

(a) **Metal excess defect due to anion vacancies :** A compound may have excess metal ion if an anion (negative ion) is absent from its appropriate lattice site creating a 'void' which is occupied by an electron. Ionic crystal which are likely to possess Schottky defect, may also develop this type of metal excess defect. When alkali metal halides are heated in an atmosphere of vapours of the alkali metal, anion vacancies are created. The anions (halide ions) diffuse to the surface of the crystal from their appropriate lattice sites to combine with the newly generated metal cations. The e^- lost by the metal atom diffuse through the crystal are known as F-centres. The main consequence of metal excess defect is the development of colour in the crystal. For example, when NaCl crystal is heated in an atmosphere of Na vapours, it becomes yellow.

Similarly, KCl crystal when heated in an atmosphere of potassium vapours, it appears violet.

(b) **Metal excess defect due to interstitial cations :** This type of defect is shown by crystals which are likely to exhibit Frenkel defect. An excess positive ion is located in the interstitial site. To maintain electrical neutrality, an electron is present in the interstitial site. An example showing this type of defect is ZnO. When ZnO is heated, it loses oxygen reversibly. The excess Zn^{++} ions are accommodated in the interstitial sites, the electrons are enclosed in the neighbouring interstitials. The yellow colour of ZnO when hot is due to these trapped electrons. These electrons also explain electrical conductivity of the ZnO crystal.

(c) **Metal Deficiency Defect**

There are many solids which are difficult to prepare in the stoichiometric composition and contain less amount of the metal as compared to the stoichiometric proportion. A typical example of this type is FeO which is mostly found with a composition of $Fe_{0.95}O$. It may actually range from $Fe_{0.93}O$ to $Fe_{0.96}O$. In crystals of FeO some Fe^{2+} cations are missing and the loss of positive charge is made up by the presence of required number of Fe^{3+} ions.

GOLDEN KEY POINTS

- On increasing temperature coordination number decreases.
- On increasing pressure; coordination number increases.
- If in a crystal complete lattice of ion along a line are disappeared, such defect is called line defect.
- Schottky defects and Frenkel defects are point defects.
- Structure of diamond :** Solids which follow the structure of diamonds known as diamond cubic. Diamond has CCP structure where carbon atoms are present at corners and face centre with four more atoms present at alternate tetrahedral voids or 50% THV so number of effective atoms

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

The carbon atoms present in THV touches its four surrounding atoms so coordination number is equal to four.

$$2r = \frac{\sqrt{3}}{4}a ; a = \frac{8r}{\sqrt{3}} ; PE = \frac{8 \times \frac{4\pi}{3} r^3}{\left(\frac{8r}{\sqrt{3}} \right)^3} = 0.34 ; \text{So \% PE} = 34$$

Illustrations

Illustration 16. In the Schottky defect

- (1) cations are missing from the lattice sites and occupy the interstitial sites
- (2) equal number of cations and anions are missing
- (3) anions are missing and electrons are present in their place
- (4) equal number of extra cations and electrons are present in the interstitial sites

Ans. (2)

Solution
22

Illustration 17. **Assertion :-** Schottky type defects is shown by crystals with high co-ordination number.

Reason :- In Schottky defect equal number of cations and anions are missing from their lattice sites.

(1) A

(2) B

(3) C

(4) D

Solution

Ans. (2)

Illustration 18. Schottky defect lowers the density of ionic crystals while Frenkel defect does not. Discuss.

Solution.

In Schottky defect, certain cations and anions are missing from the crystal lattice. Therefore, the density of the crystal decreases. However, in Frenkel defect the ions do not leave the lattice but they simply change their positions from lattice points to the interstitial spaces. As a result, the density of the crystal remains unchanged.

BEGINNER'S BOX-2

- The edge length of face centred cubic unit cell having rock salt structure is 508 pm. If the radius of the cation is 110 pm, the radius of the anion is—
(1) 144 pm (2) 288 pm (3) 618 pm (4) 398 pm
- In a solid 'AB' having the NaCl structure, 'A' atoms occupy the every CCP and B atoms are in OHV. If all the face-centred atoms along one of the axes are removed, then the resultant stoichiometry of the solid is—
(1) AB_2 (2) A_2B (3) A_4B_3 (4) A_3B_4
- How many unit cells are present in a cube shaped ideal crystal of NaCl of mass 1.00 g ?
[Atomic mass : Na = 23, Cl = 35.5]
(1) 5.14×10^{21} (2) 1.28×10^{21} (3) 1.71×10^{21} (4) 2.57×10^{21}
- A solid AB has the NaCl structure. If radius of the cation A^+ is 120 pm, the maximum value of the radius of the anion B^- is
(1) 290 pm (2) 350 pm (3) 250 pm (4) 400 pm
- If the distance between Na^+ and Cl^- ions in sodium chloride crystal is x pm, then length of the edge of the unit cell is
(1) 2x pm (2) 4x pm (3) x/2 pm (4) x/4 pm
- HCP crystal is made of A ions and B ions are arranged in $2/3^{rd}$ of octahedral voids. The simplest formula of unit cell is
(1) A_4B_6 (2) A_6B_4 (3) A_2B_3 (4) A_3B_2
- A FCC crystal of O^{2-} (oxide) ions has M^{+n} ions in 50% of octahedral voids, then the value of n is
(1) 2 (2) 3 (3) 4 (4) 1
- If the edge length of a KCl unit cell is 488 pm, what is the length of KCl bond if it crystallises in the FCC structure ?
(1) 122 pm (2) 244 pm (3) 488 pm (4) 974 pm
- In a solid lattice, the cation has left a lattice site and is located at interstitial position, the lattice defect is
(1) interstitial defect (2) vacancy defect (3) Frenkel defect (4) Schottky defect

ANSWER KEY

BEGINNER'S BOX-1	Que.	1	2	3	4	5					
	Ans.	3	2	2	4	1					
BEGINNER'S BOX-2	Que.	1	2	3	4	5	6	7	8	9	
	Ans.	1	4	4	1	1	4	3	2	3	

EXERCISE-I (Conceptual Questions)

Build Up Your Understanding

INTRODUCTION

- $a \neq b \neq c$, $\alpha = \gamma = 90^\circ$, $\beta \neq 90^\circ$ represents
 - tetragonal system
 - orthorhombic system
 - monoclinic system
 - triclinic system
- The most unsymmetrical crystal system is :
 - Cubic
 - Hexagonal
 - Triclinic
 - Orthorhombic
- Bravais lattices are of
 - 10 types
 - 8 types
 - 7 types
 - 14 types
- The crystal system of a compound with unit cell dimensions $a = 0.387$, $b = 0.387$ and $c = 0.504$ nm and $\alpha = \beta = 90^\circ$ and $\gamma = 120^\circ$ is :
 - Cubic
 - Hexagonal
 - Orthorhombic
 - Rhombohedral

ANALYSIS OF CUBIC CRYSTAL

- In a simple cubic cell, each point on a corner is shared by
 - 2 unit cells
 - 1 unit cell
 - 8 unit cells
 - 4 unit cells
- In a face centred cubic cell, an atom at the face contributes to the unit cell
 - 1 part
 - 1/2 part
 - 1/4 part
 - 1/8 part
- In a body centred cubic cell, an atom at the body centre is shared by
 - 1 unit cell
 - 2 unit cell
 - 3 unit cells
 - 4 unit cells
- Which of the following type of cubic lattice has maximum number of atoms per unit cell ?
 - Simple cubic
 - Body centred cubic
 - Face centred cubic
 - All have same
- The number of atoms present in a unit cell of a monoatomic element of a simple cubic lattice, body-centred cubic and face centred cubic respectively are
 - 8, 9 and 14
 - 1, 2 and 4
 - 4, 5 and 6
 - 2, 3 and 5

- Which one of the following is a primitive unit cell ?
 - Simple cubic
 - BCC
 - FCC
 - bcc and fcc both
- In a body centred cubic unit cell, a metal atom at the centre of the cell is surrounded by how many other metal atoms :
 - 8
 - 6
 - 12
 - 4
- A compound is formed by elements A and B. This crystallises in the cubic structure when atoms A are at the corners of the cube and atoms B are at the centre of the body. The simplest formula of the compound is
 - AB
 - AB_2
 - A_2B
 - AB_4
- A compound formed by elements A and B has cubic structure in which A atoms are at the corners of the cube and B atoms are at the face centres. The formula of the compound will be
 - A_4B_3
 - A_2B
 - AB_3
 - A_2B_3
- Sodium metal crystallises in BCC lattice with the cell edge length (a) = 42.29 Å. What is the radius of sodium atom ?
 - 1.86 Å
 - 1.90 Å
 - 18.3 Å
 - 1.12 Å
- An element has BCC structure having unit cells 12.08×10^{23} . The number of atoms in these cells is
 - 12.08×10^{23}
 - 24.16×10^{23}
 - 48.38×10^{23}
 - 12.08×10^{22}
- A metal has BCC structure and the edge length of its unit cell is 3.04 Å. The volume of the unit cell in cm^3 will be
 - $1.6 \times 10^{-21} \text{ cm}^3$
 - $2.81 \times 10^{-23} \text{ cm}^3$
 - $6.02 \times 10^{-23} \text{ cm}^3$
 - $6.6 \times 10^{-24} \text{ cm}^3$

CRYSTAL DENSITY

- An element having BCC geometry has atomic mass 50. Calculate the density of the unit cell, if its edge length is 290 pm.
 - 6.81 g cm^{-3}
 - 3.40 g cm^{-3}
 - 13.62 g cm^{-3}
 - 1.23 g cm^{-3}
- A metal (atomic mass = 50) has a body centred cubic crystal structure. The density of metal is 5.96 g cm^{-3} . Find the volume of the unit cell.
 - $13.9 \times 10^{-24} \text{ cm}^3$
 - $27.8 \times 10^{-24} \text{ cm}^3$
 - $6.95 \times 10^{-24} \text{ cm}^3$
 - $55.6 \times 10^{-24} \text{ cm}^3$

19. An element crystallises in BCC structure. The edge length of its unit cell is 288 pm. If the density of the crystal is 7.2 g cm^{-3} , what is the atomic mass of the element?
 (1) 51.8 (2) 103.6
 (3) 25.9 (4) 207.2
20. An element, density 6.8 g cm^{-3} occurs in BCC structure with cell edge 290 pm. Calculate the number of atoms present in 200 g of the element.
 (1) 2.4×10^{42} (2) 1.2×10^{42}
 (3) 1.2×10^{24} (4) 2.4×10^{24}
21. An element A crystallises in fcc structure. 200 g of this element has 4.12×10^{24} atoms. The density of A is 7.2 g cm^{-3} . Calculate the edge length of the unit cell.
 (1) $26.97 \times 10^{-24} \text{ cm}$ (2) 299.9 pm
 (3) $5 \times 10^{-12} \text{ cm}$ (4) 2.99 cm
22. Density of Li atom is 0.53 g cm^{-3} . The edge length of Li is 3.5 Å. Find out the number of Li atoms in an unit cell. ($N_A = 6.023 \times 10^{23}$), ($M = 6.94 \text{ g mol}^{-1}$)
 (1) 2 (2) 8 (3) 4 (4) 6

CLOSE PACKING OF IDENTICAL SOLID SPHERES

23. The coordination number of hexagonal closest packed (HCP) structure is
 (1) 12 (2) 10 (3) 8 (4) 6
24. The ABAB close packing and ABC ABC close packing are respectively called as
 (1) hexagonal close packing(hcp) and cubic close packing (ccp)
 (2) ccp and hcp
 (3) body centred cubic (bcc) packing and hexagonal close packing (hcp)
 (4) hcp and bcc
25. The space occupied in BCC arrangement is
 (1) 74% (2) 70% (3) 68% (4) 60.4%
26. The vacant space in BCC unit cell is
 (1) 32% (2) 10% (3) 23% (4) 46%
27. The space occupied by spheres of equal size in three dimensions in both HCP and CCP arrangement is
 (1) 74% (2) 70% (3) 60.4% (4) 52.4%
28. The empty space in the HCP and CCP is about
 (1) 26% (2) 30% (3) 35% (4) 40%
29. Which one of the following is not a close packing ?
 (1) hcp (2) ccp (3) bcc (4) fcc

30. Close packing is maximum in the crystal lattice of
 (1) Simple cubic
 (2) Face centred
 (3) Body centred
 (4) Simple cubic and body centred
31. Which of the following has HCP structure ?
 (1) Al (2) Mg (3) Cu (4) Ni
32. All noble gases crystallise in the CCP structure except
 (1) Helium (2) Neon (3) Argon (4) Krypton
33. If the coordination number of an element in its crystal lattice is 8, then packing is :
 (1) FCC (2) HCP
 (3) BCC (4) None of the above

HOLES / VOIDS IN CRYSTALS

34. A tetrahedral void in a crystal implies that
 (1) shape of the void is tetrahedral
 (2) molecules forming the void are tetrahedral in shape
 (3) the void is surrounded tetrahedrally by four spheres
 (4) the void is surrounded by six spheres
35. In a closest packed lattice, the number of octahedral sites as compared to tetrahedral ones will be
 (1) Equal (2) Half
 (3) Double (4) One fourth
36. The coordination number of a cation occupying an octahedral hole is
 (1) 4 (2) 6 (3) 8 (4) 12
37. The size of an octahedral void formed in a closest packed lattice as compared to tetrahedral void is
 (1) Equal (2) Smaller
 (3) Larger (4) Not definite
38. The coordination number of a cation occupying a tetrahedral hole is
 (1) 4 (2) 6 (3) 8 (4) 12
39. Number of tetrahedral voids per atom in a crystal lattice is :
 (1) 1 (2) 2 (3) 4 (4) 8
40. A compound contains P and Q elements. Atoms Q are in CCP arrangement while P occupy all tetrahedral sites. Formula of compound is :
 (1) PQ (2) PQ_2 (3) P_2Q (4) P_3Q
41. If 'Z' is the number of atoms in the unit cell that represents the closest packing sequence ABCABC---, the number of tetrahedral voids in the unit cell is equal to
 (1) Z (2) 2Z (3) Z/2 (4) Z/4

IONIC CRYSTAL

- 42.** The limiting radius ratio for tetrahedral shape is
(1) 0 to 0.155 (2) 0.155 to 0.225
(3) 0.225 to 0.414 (4) 0.414 to 0.732
- 43.** For an octahedral arrangement the lowest radius ratio limit is
(1) 0.155 (2) 0.732 (3) 0.414 (4) 0.225
- 44.** If the radius ratio is in the range of 0.414 - 0.732 then the co-ordination number will be :
(1) 2 (2) 4 (3) 6 (4) 8
- 45.** In NaCl crystal r^+/r^- ratio is :
(1) 0.4 (2) 0.98 (3) 1.0 (4) 0.52
- 46.** Which one of the following statements is incorrect about rock salt type ?
(1) It has fcc arrangement of Na^+
(2) Na^+ and Cl^- ions have a co-ordination number of 6 : 6
(3) A unit cell of NaCl consists of four NaCl units
(4) All halides of alkali metals have rock-salt type structure
- 47.** In sodium chloride, Cl^- ions form ccp arrangement. Which site does Na^+ ions will occupy in this structure ?
(1) Cubic (2) Tetragonal
(3) Octahedral (4) Trigonal bipyramidal
- 48.** The positions of Cl^- ions in NaCl structure are
(1) Corners of the cube
(2) Centres of faces of the cube
(3) Corners as well as centres of the faces of the cube
(4) Edge centres of the cube
- 49.** The number of NaCl units present in a unit cell of NaCl are
(1) 1 (2) 2 (3) 4 (4) 8
- 50.** The tetrahedral voids formed by ccp arrangement of Cl^- ions in rock salt structure are
(1) Occupied by Na^+ ions
(2) Occupied by Cl^- ions
(3) Occupied by either Na^+ or Cl^- ions
(4) Vacant
- 51.** The structure of MgO is similar to NaCl. The co-ordination number of Mg is
(1) 2 (2) 6 (3) 4 (4) 8
- 52.** The co-ordination number of Cs^+ and Cl^- ions in CsCl structure is
(1) 4 : 4 (2) 6 : 6 (3) 8 : 8 (4) 4 : 8
- 53.** A unit cell of CsCl consists of
(1) one CsCl unit (2) two CsCl units
(3) four CsCl units (4) eight CsCl units
- 54.** The NaCl structure can be converted into CsCl structure
(1) by application of high pressure
(2) by heating to 760 K
(3) both by heat and pressure
(4) the conversion is not possible
- 55.** TlCl has structure similar to CsCl. The co-ordination number of Tl^+ is
(1) 4 (2) 6 (3) 10 (4) 8
- 56.** The co-ordination number of Zn^{2+} and S^{2-} ions in the zinc blende (ZnS) type structure is
(1) 4 : 4 (2) 6 : 6 (3) 8 : 8 (4) 4 : 8
- 57.** The co-ordination number of calcium fluoride (CaF_2) type structure is
(1) 1 : 2 (2) 4 : 4 (3) 4 : 8 (4) 8 : 4
- 58.** The number of formula units in a unit cell of fluorite is
(1) 2 (2) 4 (3) 6 (4) 8
- 59.** 4 : 4 Co-ordination is found in
(1) ZnS (2) CuCl (3) AgI (4) All
- 60.** Antifluorite structure is derived from fluorite structure by
(1) Heating fluorite crystal lattice.
(2) Subjecting fluorite structure to high pressure.
(3) Interchanging the positions of positive and negative ions in the lattice.
(4) All of the above
- 61.** A binary solid (A^+B^-) has a zinc blend structure with B^- ions constituting the lattice and A^+ ions occupying 25% tetrahedral holes. The formula of solid is.
(1) AB (2) A_2B (3) AB_2 (4) AB_4
- 62.** The radius of Na^+ is 95 pm and that of Cl^- ion is 181 pm. Hence the co-ordination number of Na^+ will be
(1) 4 (2) 6 (3) 8 (4) 12
- 63.** The ionic radii of Rb^+ and I^- are 1.46 and 2.16 Å respectively. The most probable type of structure exhibited by it is
(1) CsCl type (2) NaCl type
(3) ZnS type (4) CaF_2 type
- 64.** A binary solid (A^+B^-) has a rock salt structure if the edge length is 400 pm and radius of cation (A^+) is 75 pm, the radius of anion (B^-) is
(1) 100 pm (2) 125 pm
(3) 250 pm (4) 325 pm

- 65.** A solid XY has a bcc structure. If the distance of closest approach between the two ions is 173 pm, the edge length of the cell is
- (1) 200 pm (2) $\frac{\sqrt{3}}{\sqrt{2}}$ pm
(3) 142.2 pm (4) $\sqrt{2}$ pm
- 66.** If the distance between Na^+ and Cl^- ions in NaCl crystal is 'a' pm, what is the length of the cell edge?
- (1) 2a pm (2) a/2 pm
(3) 4a pm (4) a/4 pm
- 67.** Potassium fluoride has NaCl-type structure. What is the distance between K^+ and F^- ions if its cell edge length is 'a' cm ?
- (1) 2a cm (2) a/2 cm
(3) 4a cm (4) a/4 cm
- 68.** KF has NaCl structure. What is the distance between K^+ and F^- in KF if density is 2.48 g cm^{-3} ?
- (1) 268.8 pm (2) 537.5 pm
(3) $155.3 \times 10^{-24} \text{ cm}$ (4) 5.375 cm
- 69.** In a NaCl type crystal distance between Na^+ and Cl^- ion is $2.814 \text{ \AA}$ and the density of solid is 2.167 g cm^{-3} then find out the value of Avogadro constant.
- (1) 6.05×10^{23} (2) 3.02×10^{23}
(3) 12.10×10^{23} (4) 9.6×10^{24}
- 70.** The density of crystalline sodium chloride is 5.85 g cm^{-3} . What is the edge length of the unit cell.
- (1) $4.06 \times 10^{-8} \text{ cm}$. (2) $1.32 \times 10^{-14} \text{ cm}$
(3) 7.8×10^{-23} (4) 9.6×10^{-24}
- 71.** A unit cell of sodium chloride has four formula units. The edge length of unit cell is 0.6 nm. What is the density of sodium chloride ?
- (1) 7.60 g cm^{-3} (2) 1.80 g cm^{-3}
(3) 9.60 g cm^{-3} (4) 6.38 g cm^{-3}

IMPERFECTIONS IN SOLIDS

- 72.** At zero kelvin, most of the ionic crystals possess
(1) Frenkel defect (2) Schottky defect
(3) Metal excess defect (4) No defect
- 73.** As a result of Schottky defect
(1) there is no effect on the density
(2) density of the crystal increases
(3) density of the crystal decreases
(4) any of the above three can happen
- 74.** Schottky as well as Frenkel defects are observed in the crystal of
(1) NaCl (2) AgBr (3) AgCl (4) MgCl_2
- 75.** Which one of the following is correct ?
(1) Schottky defect lowers the density
(2) Frenkel defect increases the dielectric constant of the crystals
(3) Stoichiometric defects make the crystals good electrical conductors
(4) All the three
- 76.** Frenkel defect is generally observed in
(1) AgBr (2) AgI (3) ZnS (4) All of these
- 77.** Frenkel defect is found in crystals in which the radius ratio is :
(1) low (2) 1.3
(3) 1.5 (4) slightly less than unity
- 78.** F-centres in an ionic crystal are
(1) lattice sites containing electrons
(2) interstitial sites containing electrons
(3) lattice sites that are vacant
(4) interstitial sites containing cations
- 79.** The correct statement regarding F-centre is
(1) Electrons are held in the lattice site of crystals
(2) F-centre imparts colour to the crystal
(3) Conductivity of the crystal increases due to F-centre
(4) All the three above

EXERCISE-I (Conceptual Questions)

ANSWER KEY

[illegible]

EXERCISE-II (Previous Year Questions)**AIPMT/NEET & AIIMS (2006-2018)****AIPMT 2006**

1. CsBr crystallises in a body centred cubic lattice. The unit cell length is 436.6 pm. Given that the atomic mass of Cs=133 and that of Br=80 amu and Avogadro number being $6.023 \times 10^{23} \text{ mol}^{-1}$ the density of CsBr is :
- (1) 42.5 g cm^{-3} (2) 0.425 g cm^{-3}
 (3) 8.25 g cm^{-3} (4) 4.25 g cm^{-3}

AIIMS 2006

2. The Ca^{2+} and F^- are located in CaF_2 crystal, respectively at face centred cubic lattice points and in –
- (1) Tetrahedral voids
 (2) Half of tetrahedral voids
 (3) Octahedral voids
 (4) half of octahedral voids

AIPMT 2007

3. NaCl is doped with $10^{-4} \text{ mol\%}$ SrCl_2 , the concentration of cation vacancies is –

$$\left[\text{Hint : Concentration of vacancies} = \frac{10^{-4}}{100} N_A \right]$$

- (1) $6.02 \times 10^{15} \text{ mol}^{-1}$ (2) $6.02 \times 10^{16} \text{ mol}^{-1}$
 (3) $6.02 \times 10^{17} \text{ mol}^{-1}$ (4) $6.02 \times 10^{14} \text{ mol}^{-1}$
4. The fraction of total volume occupied by the atoms present in a simple cube is –

(1) $\frac{\pi}{6}$ (2) $\frac{\pi}{3\sqrt{2}}$ (3) $\frac{\pi}{4\sqrt{2}}$ (4) $\frac{\pi}{4}$

AIPMT 2008

5. Percentage of free space in a body centred cubic unit is :
- (1) 32% (2) 34%
 (3) 28% (4) 30 %
6. If 'a' stands for the edge length of the cubic systems: simple cubic, body centred cubic and face centred cubic, then the ratio of radii of the spheres in these system will be respectively.

(1) $\frac{1}{2}a : \sqrt{3}a : \frac{1}{\sqrt{2}}a$ (2) $\frac{1}{2}a : \frac{\sqrt{3}}{2}a : \frac{\sqrt{2}}{2}a$
 (3) $1a : \sqrt{3}a : \sqrt{2}a$ (4) $\frac{1}{2}a : \frac{\sqrt{3}}{4}a : \frac{1}{2\sqrt{2}}a$

7. Which of the following statement is not correct ?
- (1) Molecular solids are generally volatile
 (2) The numbers of carbon atoms in a unit cell of diamond is 8
 (3) The number of Bravais lattices in which a crystal can be categorized is 14
 (4) The fraction of the total volume occupied by the atoms in a primitive cell is 0.48

AIPMT 2009

8. Lithium metal crystallises in a body centred cubic crystal. If the length of the side of the unit cell of lithium is 351 pm, the atomic radius of the lithium will be :-
- (1) 300.5 pm (2) 240.8 pm
 (3) 151.8 pm (4) 75.5 pm
9. Copper crystallises in a face-centred cubic lattice with a unit cell length of 361 pm. What is the radius of copper atom in pm ?
- (1) 108 (2) 128
 (3) 157 (4) 181

AIPMT 2010

10. AB crystallizes in a body centred cubic lattice with edge length 'a' equal to 387 pm. The distance between two oppositely charged ions in the lattice is :-
- (1) 300 pm (2) 335 pm
 (3) 250 pm (4) 200 pm

AIIMS 2010

11. In a trigonal crystal, which statement is incorrect
- (1) All the axial length and axial angle are equal
 (2) All the three axial lengths are equal
 (3) All the three axial angles are equal
 (4) Two axial angles are same and one is different

AIPMT Mains. 2011

12. A solid compound XY has NaCl structure. If the radius of the cation is 100 pm the radius of the anion (Y^-) will be :-
- (1) 165.7 pm
 (2) 275.1 pm
 (3) 322.5 pm
 (4) 241.5 pm

AIIMS 2011

- 13.** Schottky defect is–
- (1) vacancy of ions
 - (2) Delocalization of ions
 - (3) Interstitial vacancy of ions
 - (4) vacancy of only cation

AIPMT Pre. 2012

- 14.** The number of octahedral void(s) per atom present in a cubic-close-packed structure is:
(1) 2 (2) 4 (3) 1 (4) 3
- 15.** A metal crystallizes with a face-centered cubic lattice. The edge of the unit cell is 408 pm. The diameter of the metal atom is:
(1) 144 pm (2) 204 pm
(3) 288 pm (4) 408 pm

AIPMT Mains 2012

- 16.** Structure of a mixed oxide is cubic close-packed (CCP). The cubic unit cell of mixed oxide is composed of oxide ions. One fourth of the tetrahedral voids are occupied by divalent metal A and the octahedral voids are occupied by a monovalent metal B. The formula of the oxide is:
- (1) $A_2B_3O_4$ (2) AB_2O_2
(3) ABO_2 (4) A_2BO_2

AIIMS 2012

- 17.** In BCC structure, contribution of corner and central atom is :-

$$(1) \frac{1}{8}, 1 \qquad (2) \frac{1}{4}, \frac{1}{8}$$

$$(3) \quad \frac{1}{8}, \frac{1}{2} \qquad (4) \quad 1, \frac{1}{2}$$

NEET-UG 2013

- 18.** The number of carbon atoms per unit cell of diamond unit cell is :-
 (1) 1 (2) 4 (3) 8 (4) 6
- 19.** A metal has a FCC lattice. The edge length of the unit cell is 404 pm. The density of the metal is 2.72 g cm^{-3} . The molar mass of the metal is :-
 (1) 20 g mol^{-1} (2) 40 g mol^{-1}
 (3) 30 g mol^{-1} (4) 27 g mol^{-1}

AIIMS 2013

- 20.** In a solid, atom M occupy CCP lattice and $1/3^{\text{rd}}$ of tetrahedral voids are occupied by atom N. Find formula of solid formed by M and N :-
- (1) M_3N_2 (2) M_2N_3
(3) M_4N_3 (4) M_3N_4

AIPMT 2014

- 21.** If a is the length of the side of a cube, the distance between the body centered atom and one corner atom in the cube will be :

(1) $\frac{2}{\sqrt{3}}a$ (2) $\frac{4}{\sqrt{3}}a$ (3) $\frac{\sqrt{3}}{4}a$ (4) $\frac{\sqrt{3}}{2}a$

AIIMS 2014

- 22.** In any compound, atom B occupies in HCP packing and A is 1/3rd of tetrahedral voids. Then empirical formula of compound is :-
 (1) B_2A_3 (2) B_3A_2 (3) AB (4) AB_2

AIPMT 2015

- 23.** A given metal crystallizes out with a cubic structure having edge length of 361 pm. If there are four metal atoms in one unit cell, what is the radius of one atom?
- (1) 127 pm (2) 80 pm
(3) 108 pm (4) 40 pm

Re-AIPMT 2015

- 24.** The vacant space in BCC lattice unit cell is :
- (1) 23% (2) 32% (3) 26% (4) 48%
- 25.** The correct statement regarding defects in crystalline solids is :-
- (1) Frenkel defect is a dislocation defect
- (2) Frenkel defect is found in halides of alkaline metals
- (3) Schottky defects have no effect on the density of crystalline solids
- (4) Frenkel defects decrease the density of crystalline solids

AIIMS 2015

- 26.** Defects in NaCl & AgCl crystals are respectively
 (1) Schottky, Frenkel (2) Frenkel, Schottky
 (3) Both Schottky (4) Both Frenkel

27. What will be value of $r_{Cs^+} + r_{Cl^-}$ in CsCl crystal having edge length 'a'

(1) $\frac{a\sqrt{3}}{2}$ (2) $a\sqrt{3}$ (3) $\frac{a\sqrt{3}}{4}$ (4) $\frac{a}{2\sqrt{2}}$

NEET-I 2016

28. Lithium has a BCC structure. Its density is 530 kg m^{-3} and its atomic mass is 6.94 g mol^{-1} . Calculate the edge length of a unit cell of Lithium metal. ($N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$)
 (1) 154 pm (2) 352 pm
 (3) 527 pm (4) 264 pm
29. The ionic radii of A^+ and B^- ions are $0.98 \times 10^{-10} \text{ m}$ and $1.81 \times 10^{-10} \text{ m}$. The coordination number of each ion in AB is :-
 (1) 6 (2) 4 (3) 8 (4) 2

NEET-II 2016

30. In calcium fluoride, having the fluorite structure, the coordination numbers for calcium ion (Ca^{2+}) and fluoride ion (F^-) are
 (1) 8 and 4 (2) 4 and 8
 (3) 4 and 2 (4) 6 and 6

AIIMS 2016

31. In a crystalline solid, X atoms occupy hcp and $\frac{1}{4}$ th of tetrahedral voids are occupied by Y atoms. Then empirical formula of crystalline solid is :-
 (1) X_2Y (2) XY_2 (3) X_4Y (4) XY
32. A metal crystallizes in bcc lattice having a radius $4\text{\AA}$. Then what will be edge length of its unit cell?
 (1) $\frac{16}{\sqrt{3}}\text{\AA}$ (2) $16\sqrt{3}\text{\AA}$ (3) $\frac{16}{\sqrt{2}}\text{\AA}$ (4) $16\sqrt{2}\text{\AA}$

NEET(UG) 2017

33. Which is the **incorrect** statement ?
 (1) Density decreases in case of crystals with Schottky's defect
 (2) NaCl(s) is insulator, silicon is semiconductor, silver is conductor, quartz is piezo electric crystal

- (3) Frenkel defect is favoured in those ionic compounds in which sizes of cation and anions are almost equal
 (4) $\text{FeO}_{0.98}$ has non stoichiometric metal deficiency defect

AIIMS 2017

34. Order of packing efficiency is :-
 (1) HCP > fcc > BCC > simple cubic
 (2) HCP $\approx$ FCC > simple cubic > BCC
 (3) BCC > HCP > simple cubic > fcc
 (4) HCP $\approx$ FCC > BCC > simple cubic
35. In a cube X atoms are present at corners and Y atoms are at face centres of a cube. The number of X and Y are :-
 (1) 8, 8 (2) 6, 8 (3) 8, 6 (4) 6, 6

NEET-II 2018

36. Iron exhibits bcc structure at room temperature. Above 900°C , it transforms to fcc structure. The ratio of density of iron at room temperature to that at 900°C (assuming molar mass and atomic radii of iron remains constant with temperature) is
 (1) $\frac{\sqrt{3}}{\sqrt{2}}$ (2) $\frac{4\sqrt{3}}{3\sqrt{2}}$ (3) $\frac{3\sqrt{3}}{4\sqrt{2}}$ (4) $\frac{1}{2}$

AIIMS 2018

37. F-centre is produced due to :-
 (1) Unpaired electron occupied anionic vacancies
 (2) Monovalent ion is replaced by bivalent ion
 (3) Ions present in cationic vacancies
 (4) Disslocation of ions
38. Which of the following is correct for ZnO :-
 (1) Impart color due to charge transfer
 (2) On heating it turns yellow
 (3) Zn can reduce hydrogen at room temprature
 (4) It sublimes on heating
39. Among the following the molecular solid is :-
 (1) $\text{SO}_{2(\text{solid})}$ (2) SiC (3) Graphite (4) ZnS
40. In any compound, atoms of A occupies in HCP packing and atoms of B is at $\frac{1}{3}$ rd of tetrahedral voids. Then emperical formula of compound is :-
 (1) A_2B_3 (2) A_3B_2 (3) B_3A (4) BA_2

EXERCISE-II (Previous Year Questions)

ANSWER KEY

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

EXERCISE-III (Analytical Questions)

Check Your Understanding

- What is the % of volume occupied by atom in BCC
(1) 58% (2) 68%
(3) 78% (4) 88%
- Coordination number in HCP is :-
(1) 6 (2) 8
(3) 12 (4) 18
- The lattice structure of group I elements is
(1) FCC (2) BCC
(3) HCP (4) CCP
- Elements Na and Mg are Crystalizes in bcc and fcc respectively, then number of atoms of Na and Mg per unit cell are respectively :-
(1) 2, 4 (2) 9, 14
(3) 14, 9 (4) 4, 2
- In a face centred cubic lattice, atom A occupies the corner positions only 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 :-
(1) A_2B_3 (2) A_2B_5
(3) A_2B (4) AB_2
- An alloy of copper, silver and gold is found to have copper constituting the fcc lattice. If silver atoms occupy the edge centres and gold is present at body centre, the alloy has a formula
(1) Cu_4Ag_2Au (2) Cu_4Ag_4Au
(3) Cu_4Ag_3Au (4) $CuAgAu$
- Expermentally it was found that a metal oxide has formula $M_{0.98}O$. Metal M, is present as M^{2+} and M^{3+} in its oxide. Fraction of the metal which exists as M^{3+} would be :-
(1) 7.01% (2) 4.08%
(3) 6.05% (4) 5.08%

EXERCISE-III (Analytical Questions)

ANSWER KEY

Que.	1	2	3	4	5	6	7	
Ans.	2	3	2	1	2	3	2	

EXERCISE-IV (Assertion & Reason)

Target AIIMS

Directions for Assertion & Reason questions

These questions consist of two statements each, printed as Assertion and Reason. While answering these Questions you are required to choose any one of the following four responses.

- (A) If both Assertion & Reason are True & the Reason is a correct explanation of the Assertion.
 (B) If both Assertion & Reason are True but Reason is not a correct explanation of the Assertion.
 (C) If Assertion is True but the Reason is False.
 (D) If both Assertion & Reason are false.

1. **Assertion :-** Metals are generally good conductors of electricity.

Reason :- Electrical conductivity of metals is due to schottky defect.

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

2. **Assertion:-** Graphite is an example of tetragonal crystal system.

Reason:- For a tetragonal system $a=b \neq c$, $\alpha=\beta=90^\circ$, $\gamma=120^\circ$.

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

3. **Assertion :-** BCC & HCP has same packing efficiency

Reason :- Both have same number of atoms per unit Cell and same arrangement.

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

4. **Assertion :-** The number of tetrahedral void is double the number of octahedral voids.

Reason :- The size of the tetrahedral void is half of that of the octahedral void.

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

5. **Assertion :-** In CsCl crystal, the Co-ordination number of Cs^+ ions is 6.

Reason :- Cl^- ion in CsCl, adopt body centred cubic arrangement.

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

6. **Assertion :-** Na_2O adopts structure similar to that of CaF_2 but positions of positive and negative ions are reversed.

Reason :- The structure of Na_2O is also called antifluorite structure.

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

7. **Assertion :-** FeO has metal deficiency defect.

Reason :- Some Fe^{+3} replace Fe^{+2} ion in crystal structure.

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

EXERCISE-IV (Assertion & Reason)

ANSWER KEY

Que.	1	2	3	4	5	6	7
Ans.	3	4	4	3	4	2	1