

Solid State

Solid \rightarrow solids are the substance which have definite shape and definite volume.

In solid the constituent particles are very close to each other and have strong force of attraction b/w them.

✓ Classification of solid \rightarrow solid can be done in following ways \rightarrow

(A) Classification based upon the arrangement of constituent particles

Depending upon the arrangement of constituent particles we have two types of solid

- (1) Crystalline solid
- (2) Amorphous solid

Crystalline solid \rightarrow The solid in which constituent particles are arranged in a definite regular arrangement is called crystalline solid - eg \rightarrow NaCl, ZnS, Cu (1)

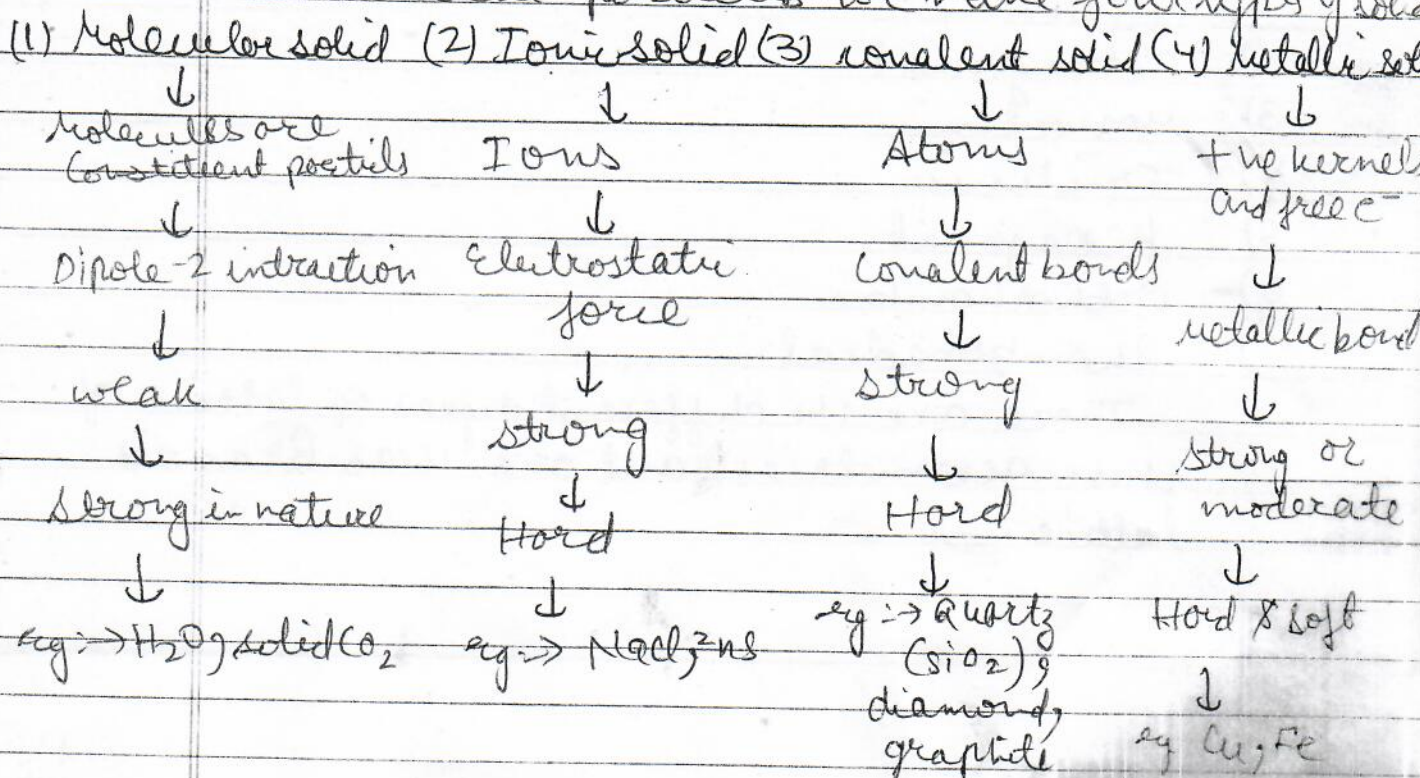
Amorphous solid \rightarrow The solid in which constituent particles are not arranged in a regular manner but are arranged in irregular manner is called amorphous solid.

eg \rightarrow Glass, rubber, plastic.

Difference b/w Crystalline and amorphous solid →

	Crystalline solid	Amorphous solid
1)	The solids in which constituent particles are arranged in regular manner	The solids in which constituent particles are arranged in irregular manner.
2)	Crystalline solid have sharp melting point.	Amorphous solid do not have sharp melting point.
3)	It undergo clean cleavage.	It do not undergo clean cleavage.
4)	It is anisotropic eg → NaCl, Zn, Cu	It is isotropic. eg → glass, rubber, plastic.

(B) Classification of solid based upon the nature of interaction b/w constituent particles
Depending upon the nature of interaction b/w constituent particles we have four types of solid



* Space lattice \rightarrow In crystalline solid, the constituent particles are arranged in a regular arrangement.

The arrangement of constituent particles in 3-dimensions within a crystal is known as space lattice.

The position of constituent particles in space lattice is known as lattice point or lattice sites.

The pos

* Unit cell \rightarrow It is the smallest repeating unit of a space lattice which when repeated over and over again in different directions gives the complete structure of crystal.

Unit cell determines the geometry of the crystal.

Depending upon the geometry of unit cell there are seven different types of unit cell \rightarrow

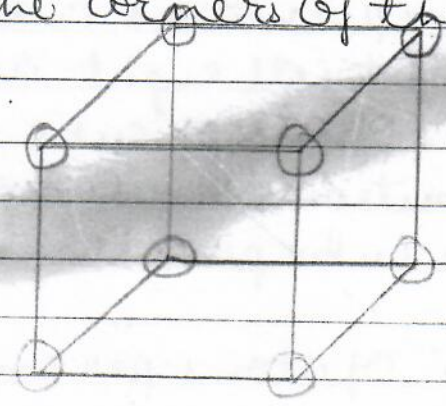
- 1) Cubic
- 2) Tetragonal
- 3) Monoclinic
- 4) Triclinic
- 5) Hexagonal
- 6) Orthorhombic
- 7) Rhombohedral

There are 14 different types of lattice of these geometries and are known as Bravais lattice.

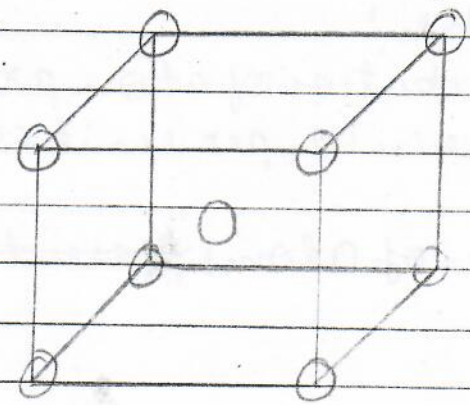
Different types of cubic unit cell \rightarrow
There are three different types of cubic unit cell -

- 1) Simple / primitive cubic unit cell
- 2) Body centred cubic unit cell (bcc)
- 3) Face centred cubic unit cell (fcc)

simple / primitive cubic unit cell \rightarrow In this unit cell the constituent particles are present at the corners of the cube -

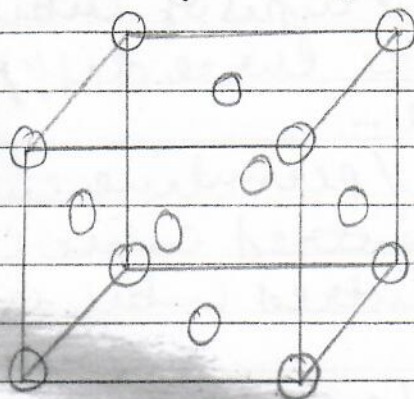


Body centred cubic unit cell \rightarrow In this unit cell constituent particles are present at the corners of the cube and in addition to this one constituent particle is present at the centre of the cube -



Face centred cubic unit cell \rightarrow In this unit cell constituent particles are present at the

Corners of the cube and in addition to this one constituent particle is present at the centre of each face of the cube.



* Number of atoms per unit cell \rightarrow
Simple / primitive cubic unit cell \rightarrow In this unit cell eight atoms are present at the corner of cube.

Contribution of atom present at the corner of the cube per unit cell = $\frac{1}{8}$

$$\therefore \text{No. of atoms per unit cell} = 8 \times \frac{1}{8} = 1$$

Body centred cubic unit cell \rightarrow In this unit cell eight atoms are present at the corner of cube in addition to this one atom is present inside the body of cube.

Contribution of atom present at the corner of the cube per unit cell = $\frac{1}{8}$

$$\begin{aligned} \therefore \text{No. of atoms present per unit cell} &= \frac{1}{8} \times 8 + 1 \\ &= 1 + 1 \\ &= 2 \end{aligned}$$

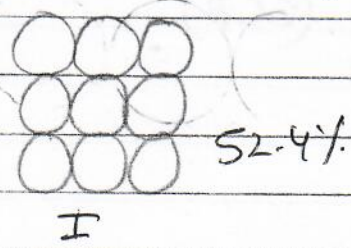
Face centred cubic unit cell \rightarrow In this type of unit cell eight atoms are present at the corner of the cube and in addition to this six atoms are present at the ^{center} face of the cube.

The contribution of atoms present at the corner of the cube per unit cell = $\frac{1}{8}$

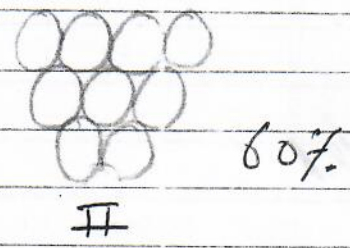
Contribution of each atom present at the centre of face towards each unit cell = $\frac{1}{2}$

$$\begin{aligned} \text{No. of atoms per unit cell} &= 8 \times \frac{1}{8} + 6 \times \frac{1}{2} \\ &= 1 + 3 \\ &= 4 \end{aligned}$$

* Close packing of crystals \rightarrow
Close packing of crystals in 2-dimension

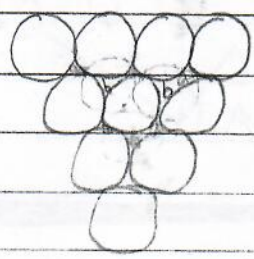


Square close packing

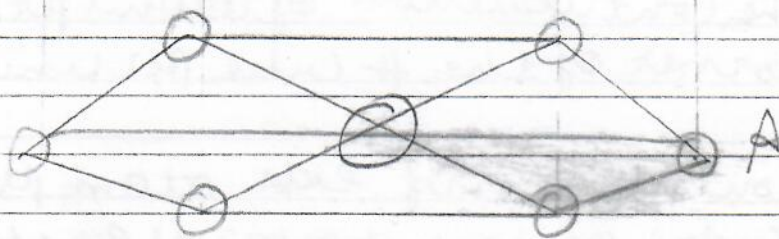
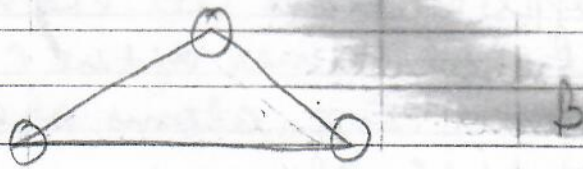
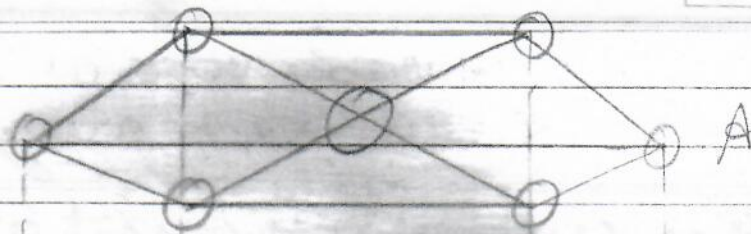


Hexagonal close packing

Close packing in 3-dimension
Case I

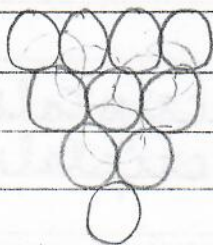


ABABAB
Hexagonal close packing (hcp)

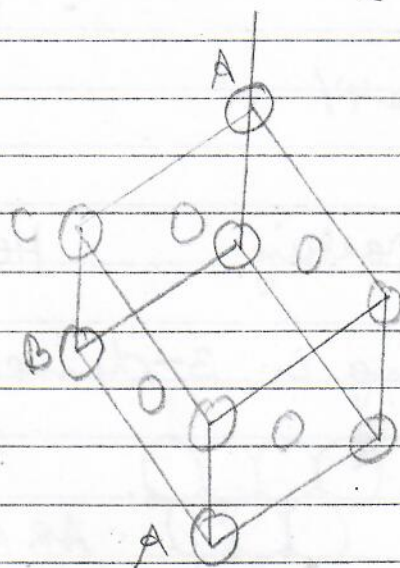


when in 3-D we have ABABAB type of close packing of atoms. This type of close packing is known as hexagonal close packing (hcp).

Case II



ABC ABC ----
 Cubic close packing
 (CCP)



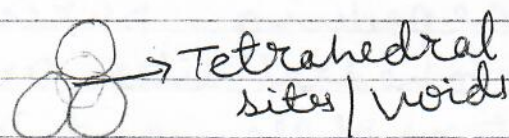
* Coordination number \rightarrow It is the number of closest constituent particles which are touching a particular constituent particle is n as its coordination number.

* Interstitial voids / sites \rightarrow During the close packing of constituent particles within the crystals some space left vacant. These vacant space left during the close packing of constituent particles in the crystal are n as interstitial sites / voids.

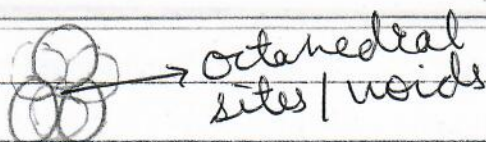
There are two types of interstitial sites / voids \rightarrow

- 1) Tetrahedral sites / voids
- 2) Octahedral sites / voids

Tetrahedral sites / voids \rightarrow When four constituent particles are arranged in a tetrahedral manner then the vacant spaces b/w these four constituent particles is n as tetrahedral sites / voids



Octahedral sites / voids \rightarrow When six constituent particles are arranged in an octahedral manner then the vacant spaces b/w these six constituent particles is n as octahedral sites / voids.



* During the close packing of 'N' constituent particles
 Then the no. of tetrahedral sites / voids = $2N$
 No. of octahedral sites / voids = N

eg \rightarrow In a hcp arrangement of atoms of element B. The two third of tetrahedral voids are occupied by atoms of element A. What is the formula of compound.

sol \rightarrow Let N be the no. of particles undergo close packing.

$$\text{No. of atom of B} = N$$

$$\text{No. of tetrahedral sites} = 2N$$

$$\begin{aligned} \text{No. of atom for A} &= 2 \times \frac{2}{3} N \\ &= \frac{4}{3} N \end{aligned}$$

$$\begin{aligned} \text{Ratio of atoms A and B} &= \frac{4}{3} N : N \\ &= 4 : 3 \end{aligned}$$

$$\therefore \text{Formula of compound} = A_4B_3$$

eg \rightarrow The atoms of element X undergo cubic close packing. During this half of the octahedral sites are occupied by the atoms of element X and the tetrahedral sites are occupied by the atoms of element Z. What will be the formula of the compound.

sol \rightarrow Let N be the no. of particles undergo close packing

No. of atoms of $X = N$

No. of octahedral sites = N

No. of octahedral sites $\neq N \times \frac{1}{2}$

No. of atoms of $Y = \frac{N}{2}$

No. of tetrahedral sites = $2N$

No. of atoms of $Z = 2N$

Ratio of atoms of X, Y & $Z = N : \frac{N}{2} : 2N$

$= 1 : \frac{1}{2} : 2$

$= 2 : 1 : 4$

Formula of compound = $X_2 Y_1 Z_4$

eg. \rightarrow In a compound oxygen ions are in hcp and aluminium ions occupies $\frac{2}{3}$ rd of the octahedral sites? What is the formula of the compound.

sol. \rightarrow Let N be the no. of particles undergo close packing

\therefore No. of ions of $O = N$

No. of octahedral sites = N

No. of ions of $Al = \frac{2}{3} \times N$

$= \frac{2N}{3}$

Ratio for ions Al and O

$\frac{2N}{3} : N$

$2 : 3$

Formula of compound = $Al_2 O_3$

eg: \rightarrow A compound is formed from element A and B in a cubic arrangement. Atoms of element A are at the corner of the cube and atoms of B are at the corner of faces. What is the formula of compound.

sol \rightarrow No. of A atoms = $8 \times \frac{1}{8} = 1$

No. of B atoms = $6 \times \frac{1}{2} = 3$

Ratio of A & B = 1:3

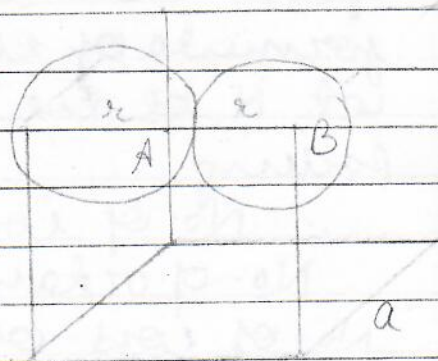
Formula of compound = AB_3

* Relationship b/w radius of the atom and the edge of the cube \rightarrow
 Let us consider 'r' be the radius of the atom and 'a' be the edge of the cube
 In simple / primitive cubic

$$AB = r + r = 2r$$

$$a = 2r \quad [\because AB = a]$$

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



In body centred cubic \rightarrow

$$AD = r + r + r + r = 4r$$

In ΔADC

$$AD^2 = DC^2 + AC^2$$

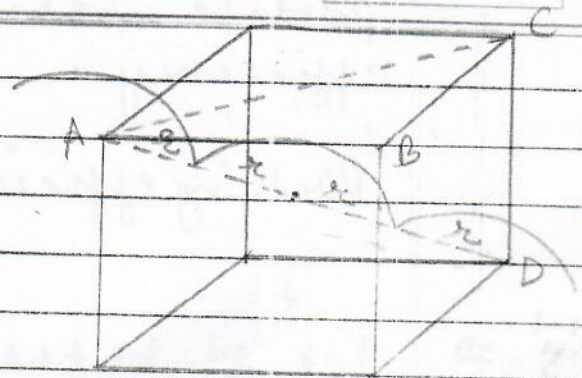
$$= a^2 + 2a^2 \quad [\text{From FCC}]$$

$$AD^2 = 3a^2$$

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

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

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



In face centred cubic \rightarrow

$$AC = r + r + r + r = 4r$$

$$AC^2 = AB^2 + BC^2$$

[From P.O.T]

$$AC^2 = a^2 + a^2$$

$$AC^2 = 2a^2$$

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

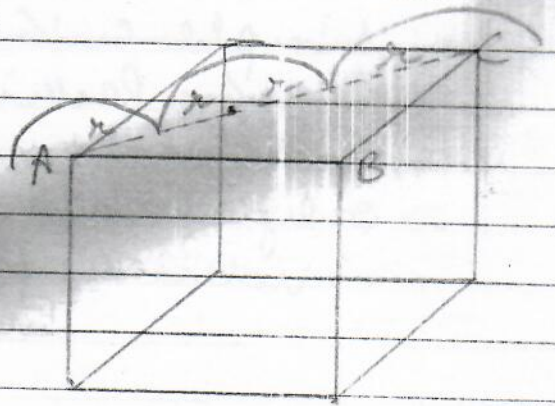
$$4r = \sqrt{2}a$$

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

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

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

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



* Packing fraction \Rightarrow The fraction of the total volume occupied by constituent particles within the crystal is known as packing fraction.

$$\text{Packing fraction} = \frac{\text{Vol. of the atoms present in unit cell}}{\text{Total vol. of the unit cell}}$$

- * Packing efficiency \rightarrow The percentage of the total volume occupied by constituent particles within the crystal is known as packing efficiency.

$$\text{Packing efficiency} = \frac{\text{no. of atoms present in unit cell}}{\text{Total vol. of unit cell}} \times 100$$

\Rightarrow Let ' r ' be the radius of atoms and ' a ' be the edge of the cubic unit cell or cube
I case

~~simple cubic~~ \rightarrow

~~Packing~~ Packing fraction in simple cubic \rightarrow
In simple cubic unit cell there is only one atom per unit cell.

$$\therefore \text{Volume of atoms present in unit cell} = 1 \times \frac{4}{3} \pi r^3$$

$$\therefore \text{Packing fraction} = \frac{\frac{4}{3} \pi r^3}{a^3}$$

For simple cube

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

$$a = 2r$$

In terms of r

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

$$= \frac{\frac{4}{3} \pi r^3}{8r^3}$$

$$= \frac{\frac{4}{3} \pi}{8}$$

$$= \frac{4 \times 22}{3 \times 8 \times 7} = \frac{11}{21} = 0.52$$

$$\begin{aligned} \text{Packing efficiency} &= 0.52 \times 100\% \\ &= \frac{52 \times 100}{100} \\ &= 52\% \end{aligned}$$

II case

Packing fraction in body centred cubic -
In case of body centred cubic unit cell there are two atoms per unit cell.

- volume of atoms present in unit cell

$$= 2 \times \frac{4}{3} \pi r^3$$

$$= \frac{8}{3} \pi r^3$$

$$\therefore \text{Packing fraction} = \frac{\frac{8}{3} \pi r^3}{a^3}$$

For bcc

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

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

In terms of r

$$\text{Packing fraction} = \frac{\frac{8}{3} \pi r^3}{\left(\frac{4r}{\sqrt{3}}\right)^3}$$

$$= \frac{\frac{8}{3} \pi r^3}{\frac{64r^3}{3\sqrt{3}}}$$

$$= \frac{8 \times \pi \times 3\sqrt{3}}{3 \times 64}$$

$$= \frac{2^2 \times 3\sqrt{3}}{7 \times 3 \times 8}$$

$$= \frac{11 \times 1.732}{7 \times 4}$$

$$= \frac{11 \times 1.732}{7 \times 4 \times 1000}$$

$$= \frac{4763}{7000}$$

$$= 0.68$$

$$\text{Packing efficiency} = 0.68 \times 100$$

$$= \frac{68}{100} \times 100$$

$$= 68\%$$

III case

Packing fraction in face centred cubic \rightarrow

In case of face centred cubic unit cell there are four atoms per unit cell.

\therefore volume of atoms present in unit cell

$$= 4 \times \frac{4}{3} \pi r^3$$

$$= \frac{16}{3} \pi r^3$$

$$\text{Packing fraction} = \frac{\frac{16}{3} \pi r^3}{a^3}$$

For face centred cubic

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

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

In terms of r

$$\text{Packing fraction} = \frac{\frac{16}{3} \pi r^3}{(2\sqrt{2}r)^3}$$

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

$$= \frac{\pi}{3\sqrt{2}}$$

$$= \frac{22 \times \frac{500}{1000}}{7 \times 3 \times 1.414}$$

= 7.07

$$= \frac{11000}{21 \times 707}$$

$$= \frac{11000}{14847}$$

$$= 0.74$$

$$\text{Packing efficiency} = 0.74 \times 100$$

$$= \frac{74 \times 100}{100}$$

$$= 74\%$$

* Density of a cubic unit cell or cubic crystal \rightarrow

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

Let 'a' be the edge of cubic unit cell express in picometer

$$\therefore \text{edge of the cube} = a \times 10^{-10} \text{ cm}$$

$$\left[\because 1 \text{ pm} = 10^{-12} \text{ m} \right]$$

$$= 10^{-12} \times 100 = 10^{-10} \text{ cm}$$

$$\text{Volume of unit cell} = (a \times 10^{-10})^3 \text{ (in pm)}$$

$$\text{Density of unit cell} = \frac{\text{Mass}}{(a \times 10^{-10})^3}$$

[where edge length is express in picometer]

Let 'Z' be the no. of atoms per unit cell and 'm' be the mass of each atom

$$\therefore \text{Mass of unit cell} = Z \times m$$

$$= \frac{Z \times M}{N_0} \quad \left[\text{where } N_0 = 6.02 \times 10^{23} \right]$$

$$m = \frac{\text{Atomic mass}}{\text{Avogadro's no.}}$$

$$\therefore \text{Density} = \frac{Z \times M}{(a \times 10^{-10})^3 \times N_0} \quad \left[\text{when edge length is in picometer} \right]$$

$$\text{Density} = \frac{Z \times M}{(a)^3 \times N_0} \quad \left[\text{when edge length is in cm} \right]$$

Q. \Rightarrow A fcc element (atomic mass = 60). has cell edge of 400 pm. what is the density of the unit cell?

Sol. \Rightarrow

$$Z = 4$$

$$M = 60$$

$$\begin{aligned} \text{Edge of cube} &= a \times 10^{-10} \text{ cm} \\ &= 400 \times 10^{-10} \text{ cm} \end{aligned}$$

$$\text{Volume of unit cell} = (400 \times 10^{-10})^3$$

$$\text{Density of unit cell} = \frac{Z \times M}{(a \times 10^{-10})^3 \times N_0}$$

$$= \frac{4 \times 60}{(400 \times 10^{-10})^3 \times 6.02 \times 10^{23}}$$

$$= \frac{240 \times 100}{64000000 \times 10^{-30} \times 602 \times 10^2}$$

$$= \frac{240 \times 100}{64000000 \times 10^{-7} \times 602}$$

$$= \frac{24000 \times 7}{64000000 \times 10 \times 602}$$

$$= \frac{49}{320000 \times 301}$$

$$= \frac{49}{96320000}$$

$$= 0.00000050872$$

Qⁿ → An element with atomic mass = 27 forms cubic unit cell with edge length 4.05×10^{-8} cm. If its density is 2.7 g per cm³ then what is the nature of lattice or unit cell?

Sol.

$$M = 27$$

$$a = 4.05 \times 10^{-8}$$

$$\text{Density} = 2.7$$

$$\text{Density} = \frac{z \times M}{(a)^3 \times N_0}$$

$$\text{Density} \times (a)^3 \times N_0 = z \times M$$

$$\frac{\text{Density} \times (a)^3 \times N_0}{M} = z$$

$$z = \frac{2.7 \times (4.05 \times 10^{-8})^3 \times 6.022 \times 10^{23}}{27}$$

$$z = \frac{2.7 \times (4.05 \times 10^{-8})^3 \times 6.022 \times 10^{23}}{10 \times 27}$$

$$= \frac{66.430125 \times 10^{-24} \times 6.022 \times 10^{23}}{10 \times 1000}$$

$$= \frac{66.430125 \times 10^{-1} \times 6022}{10000}$$

$$= \frac{66.430125 \times 6022}{10000 \times 10}$$

$$= \frac{66400042.21275}{100000}$$

$z = 4$
 ∴ $z = 4$ the unit cell is fcc unit cell.

eg: \rightarrow Na has a bcc structure with nearest neighbour distance 365.9 pm . Calculate density of crystal.

Sol.

$$M = 23, \quad z = 2$$

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

$$2r = \frac{\sqrt{3}}{4} a$$

$$365.9 = \frac{\sqrt{3}}{2} a$$

$$\frac{2 \times 365.9}{\sqrt{3}} = a$$

$$a = \frac{2 \times 365.9}{\sqrt{3}} \text{ pm}$$

~~$$z = 2$$~~

~~$$\text{Density} = \frac{z \times M}{a^3}$$~~

~~$$a = \frac{2 \times 365.9}{\sqrt{3}} \times 10^{-10} \text{ cm}$$~~

~~$$= \frac{731.8}{1.732} \times \frac{10}{10}$$~~

~~$$= \frac{731.8}{1.732} = 422.5$$~~

$$\text{Density} = \frac{z \times M}{(a \times 10^{-10})^3 \times N_0}$$

$$= \frac{2 \times 23}{(422.5 \times 10^{-10})^3 \times 6.02 \times 10^{23}}$$

$$\begin{aligned}
 &= \frac{46}{75418890 \cdot 625 \times 10^{-30} \times 6.02 \times 10^{23}} \\
 &= \frac{46 \times 1000 \times 100}{75418890625 \times 10^{-7} \times 602} \\
 &= \frac{4600000 \times 7}{75418890625 \times 602 \times 10} \\
 &= \frac{3220000}{45402172156.2} \\
 &= 1.01 \text{ g cm}^{-3}
 \end{aligned}$$

eg. \rightarrow A metal having atomic mass = 50 has a bcc structure. The density of metal is 5.96 g cm^{-3} . Find the vol of unit cell.

Sol.

$$\begin{aligned}
 M &= 50 \\
 z &= 2 \\
 \text{Density} &= 5.96 \\
 \text{Density} &= \frac{z \times M}{(a)^3 \times N_0} \\
 V_{\text{cell}} &= \frac{z \times M}{\text{Density} \times N_0} \\
 &= \frac{2 \times 50}{5.96 \times 6.022 \times 10^{23}}
 \end{aligned}$$

$$\begin{aligned}
 &= \frac{2 \times (50 \text{ g mol}^{-1})}{(5.96 \text{ g cm}^{-3}) \times (6.022 \times 10^{23} \text{ mol}^{-1})} \\
 &= \frac{100}{(5.96 \text{ cm}^{-3}) \times 6.022 \times 10^{23}} \\
 &= \frac{100}{35.89112 \times 10^{-24}} \\
 &= 27.86 \times 10^{-24} \text{ cm}^3
 \end{aligned}$$

eg \Rightarrow An element with density 11.2 g cm^{-3} forms a fcc lattice with edge length of $4 \times 10^{-8} \text{ cm}$. Calculate the atomic mass of the element.

Sol. \rightarrow

Density = 11.2

edge length = 4×10^{-8}

$z = 4$

No. \rightarrow

$$\text{Density} = \frac{z \times M}{(a)^3 \times N_0}$$

$$\text{Density} \times (a)^3 \times N_0 = M$$

$$M = \frac{11.2 \times (4 \times 10^{-8})^3 \times 6.02 \times 10^{23}}{4}$$

$$= \frac{11.2 \times 64 \times 10^{-24} \times 6.02 \times 10^{23}}{4}$$

$$= \frac{112 \times 64 \times 10^{-1} \times 602}{10 \times 100 \times 4}$$

$$\begin{aligned}
 &= \frac{112 \times 8 \times 602}{5 \times 100 \times 10} \\
 &= \frac{57424}{625} \\
 &= 107.94.
 \end{aligned}$$

* Imperfections or defects in solids → Any deviation from perfectly ordered arrangement of a constituent particles in crystal is known as imperfections or defects in solids.

There are two types of imperfections/defects in crystal →

- (1) Point defect
- (2) Line defect

Point defect → when the deviation or irregularity exists around a point on a constituent particle in a crystal. The defect is known as point defect.

There are following types of point defects →

- (1) Stoichiometric defect
- (2) Non stoichiometric defect
- (3) Impurity defect

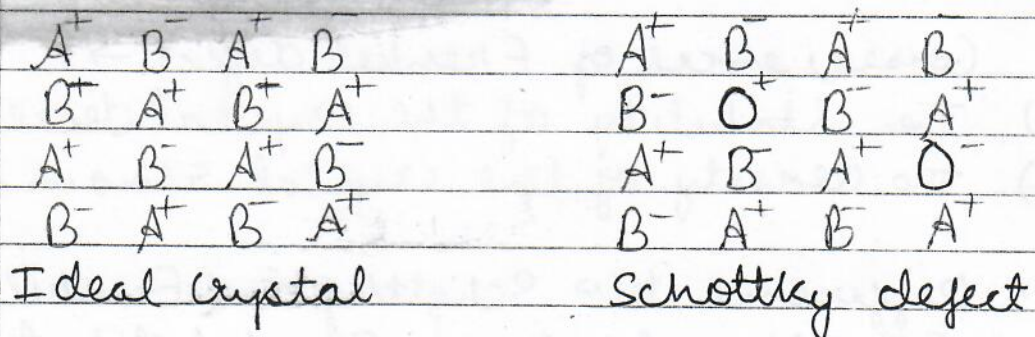
⇒ Stoichiometric defect → If the imperfections or defect occurs in such a way that the ratio b/w cation and anion remains same as represented by its molecular formula =

The defect is then K as stoichiometric defect and the compound in which stoichiometric defect exists is K as stoichiometric compound.

In ionic crystal there are two types of stoichiometric compound defect \rightarrow

- ① Schottky defect
- ② Frenkel defect

\Rightarrow Schottky defect \rightarrow The defect which arises due to missing of equal numbers of cation and anion from the crystal lattice is K as Schottky defect.



Schottky defect is shown by crystal which have \rightarrow

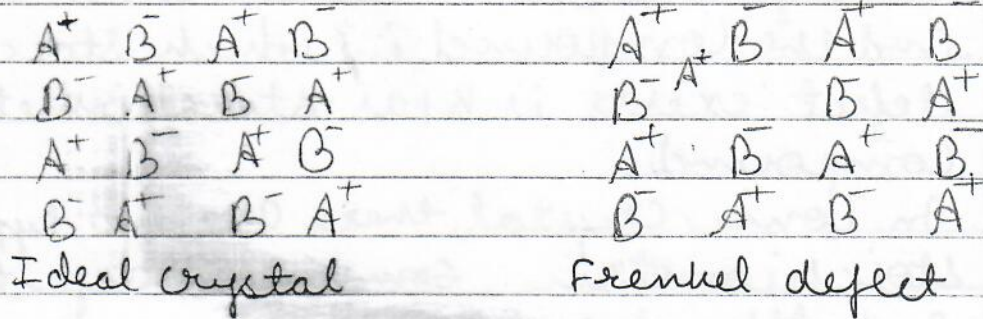
- 1) High coordination number
- 2) Identical size of cation and anion
eg: \rightarrow NaCl, KBr, KCl, AgBr, CsCl.

Consequences of Schottky defect \rightarrow

- 1) The stability of the crystal decreases.
- 2) The density of the crystal decreases.

\Rightarrow Frenkel defect \rightarrow The defect which arises due to missing of cation or anion

from their normal position and occupies the interstitial sites are called as Frenkel defect.



Frenkel defect is shown by crystal which have \rightarrow

- 1) Low coordination number
- 2) The size of anion are bigger than the size of cation.

eg \rightarrow AgCl, AgBr, AgI

Consequences of Frenkel defect \rightarrow

- 1) The stability of the crystal decreases.
- 2) The density of the crystal remain same.

\Rightarrow Difference b/w Schottky and Frenkel defect \rightarrow

Schottky defect	Frenkel defect
1) The defect which arises due to missing of equal number of cation and anion from the crystal.	The defect which arises due to missing of cation or anion from their normal position and occupies interstitial sites.
2) This defect is shown by those compound which have high coordination no.	This defect is shown by those compound which have low coordination no.

- | | | |
|----|---|---|
| 3) | This defect is shown by those compound which have identical size of cation and anion. | This defect is shown by those compound which have size of anion are bigger than size of cation. |
| 4) | The density of the crystal decreases. | The density of the crystal remains same. |
| 5) | eg \rightarrow NaCl, KBr, KCl, AgBr, CsCl | eg \rightarrow AgCl, AgBr, AgI |

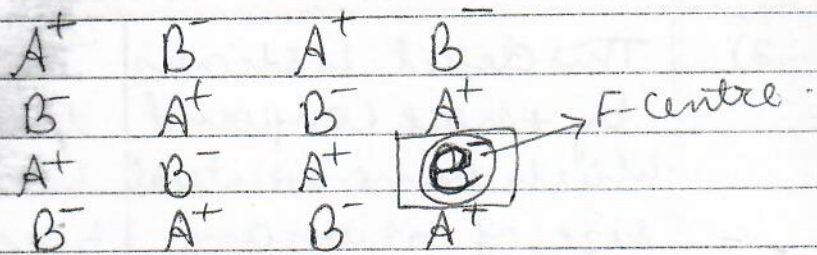
\Rightarrow Non-stoichiometric defect \rightarrow If the imperfections or defects occur in such a way that the ratio b/w cation and anion is different then the ratio represent by its molecular formula. This defect is known as non-stoichiometric defect and the compounds in which these defects exist are known as non-stoichiometric compound.

Metal excess defect \rightarrow In metal excess defect the number of metal ion i.e. cations are more than anions. This can occur in two ways \rightarrow

1) By anion vacancies \rightarrow In this defect the anion is missing from its position and

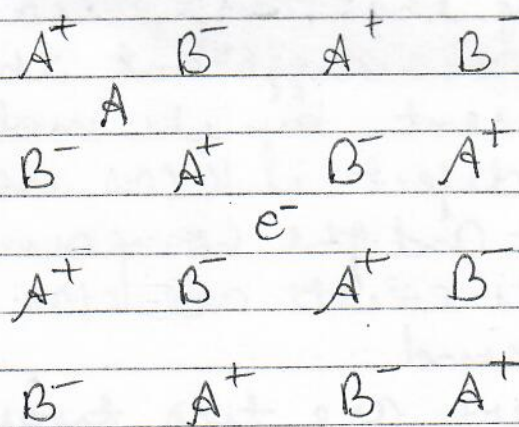
its electron remains in the lattice to maintain neutrality.

trapped in anion vacancy in metal excess defect is known as F-centre.



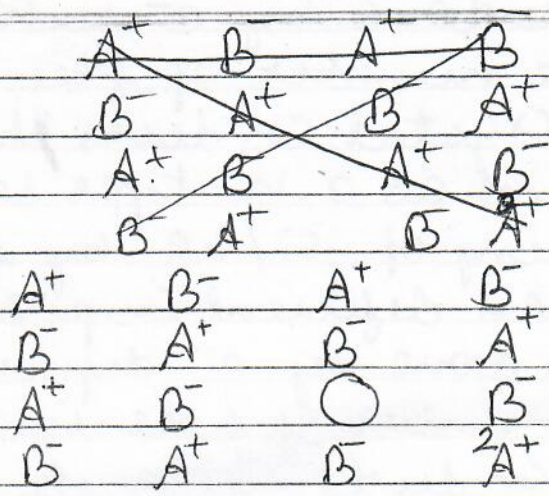
F-centre is responsible for the colour of the crystal.

- 2) Extra cation occupying at interstitial sites \rightarrow In this defect an extra cation is present at the interstitial sites and an electron is also present in interstitial site to maintain the electrical neutrality.

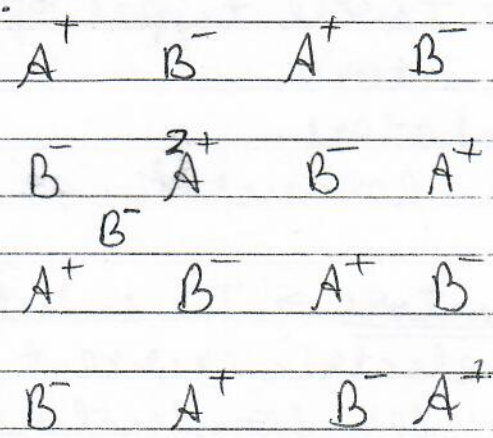


metal deficiency defect \rightarrow In this defect the metal ion i.e. cations are less than anion - This can occur in two ways \rightarrow

- 1) By cation vacancies \rightarrow In this defect the cation i.e. metal ion is missing from its position and its neighbouring cation acquires extra +ve charge to maintain electrical neutrality.



2) Extra anion occupying at interstitial sites \rightarrow In this defect extra anion is present at interstitial site and the neighbouring cation acquires extra +ve charge to maintain electrical neutrality.



\Rightarrow Impurity defect \rightarrow The defect in crystal which arises due to presence of some impurity at the lattice site in place of host constituent particle is known as impurity defect.

* Doping \rightarrow It is the process of adding small impurities into pure crystal to change its properties.

Doping can be done in two ways \rightarrow

- 1) By electron rich impurities \rightarrow when doping is done by e^- rich impurities then the number of free e^- increases and the crystal conducts electricity and ~~not~~ behave as a n-type semiconductor.
eg \Rightarrow Doping of Si/Ge by P/As
- 2) By electron deficient impurities \rightarrow when doping is done by e^- deficient impurities then the number of hole increases and the crystal conducts electricity and behave as p-type semiconductor.
eg \Rightarrow Doping of Si/Ge by Al/Ga/In

* Different types of solid on the basis of electrical properties

Depending upon the electric property we have three types of solids

- (1) Conductors
- (2) Insulators
- (3) Semi-conductors

Conductors \rightarrow The substances which allows the electric current to pass through them are called conductors.

There are two types of conductors

- (i) Metallic conductors \rightarrow The conductors which conducts the electricity without undergoing a change are called metallic conductors.
eg \Rightarrow Fe, Cu
- (ii) Electrolytic conductors \rightarrow The conductors which conduct the electricity by undergoing a

decomposition or a change are called electrolytic conductors.
eg \Rightarrow NaCl, KCl

Insulators \Rightarrow The substances which do not allow the electric current to pass through them are called insulators. Insulators have very-very low conductivity of the range $10^{-20} - 10^{-10} \text{ ohm}^{-1}$.

Semi-conductors \Rightarrow The substances which have conductivity b/w conductors and insulators are called semi-conductors. Semi-conductors have conductivity b/w $10^{-6} - 10^4 \text{ ohm}^{-1}$.

* Conductors, insulators and semi-conductors on the basis of band theory \rightarrow

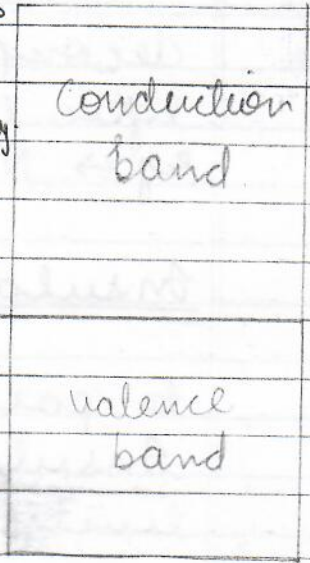
In solid on the basis of band theory we have two types of band valence band and conduction band. Valence band are filled with electrons whereas conduction band are empty.

Depending upon the energy gap b/w the valence band and conduction band we have three types of solids \rightarrow

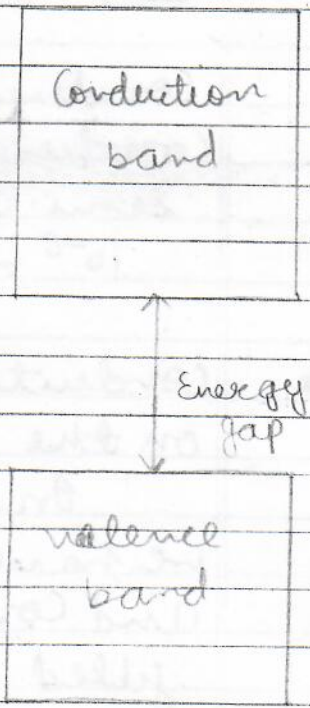
- (1) Conductors
- (2) Insulators
- (3) Semi-conductors

Conductors \rightarrow In conductors, there is a very

Small gap b/w the valence band and conduction band. Due to this e^- from valence band can easily move towards conduction band and thus conducts electricity.

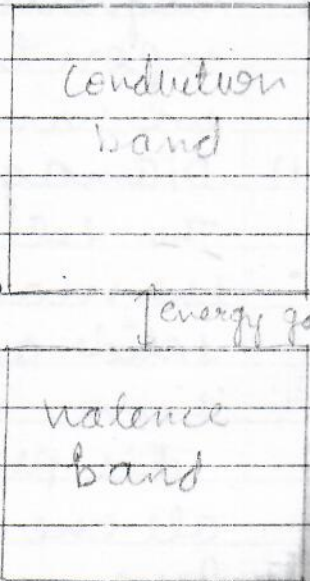


Insulators \Rightarrow In insulators there is a very large energy gap b/w valence band and conduction band. Due to this e^- from valence band cannot easily move to conduction band and thus do not conduct electricity.



Semi-conductors \Rightarrow In semi conductors there is a small energy gap b/w valence band and conduction band which is more

than conductor and less than insulators. In semi conductors some of the electron in valence band moves to conduction band and thus conducts electricity to some extent.



* Effect of temperature on conductivity of semi conductors →

⇒ Conductivity of temper semi-conductor increase with increase in temperature. Because the energy gap b/w valence band and conduction band is small. Due to this increase in temperature the energy of e^- in valence band increases and e^- can easily moves towards the conduction band and thus conducts electricity fast.

Effect of temperature on conductivity of metals

⇒ ~~Conductivity of metals increase with increase in temper~~
 Conductivity of metals decreases with increase in temperature. Because the energy of +ve kernels and free e^- present in metal increases. Therefore the +ve kernels starts vibrating. The +ve kernels create obstacles on the path.

of free e^- . \therefore Conductivity decreases.

* Magnetic properties of solid \rightarrow Depending upon the magnetic property of solids we have following types of solids

1) Diamagnetic solid (Diamagnetism) \rightarrow
The solids which are weakly repel by the magnetic field are known as diamagnetic solid and this property is known as diamagnetism.

This property arises due to ~~un~~ when all the e^- are paired.

2) Paramagnetic solid (Paramagnetism) \rightarrow
 \rightarrow The solids which are weakly attracted by the magnetic field are known as paramagnetic solid and this property is known as paramagnetism.

This property arise due to unpaired electron.

3) Ferromagnetic solid (Ferromagnetism) \rightarrow The solids which are strongly attracted by magnetic field and shows permanent magnetism even when the magnetic field is removed are known as ferromagnetic solid and this property is known as ferromagnetism.

a) Ferrimagnetic solid (Ferrimagnetism) \rightarrow
Some solids which appears to be ferromagnetic but are in fact weakly attracted by magnetic field are known as ferrimagnetic solid.

In these solids the magnetic moments are in parallel and antiparallel direction with unequal number. As a result they

have certain resultant magnetic moment which is permanent in nature. This property is known as ferromagnetism.

- b) Anti ferromagnetic solid (Anti ferromagnetism)
→ There are certain solid which appears to be ferromagnetic but are not attracted by magnetic field.

In these solids the magnetic moment are in parallel and anti parallel direction with equal no. As a result they have zero magnetic moment and thus not attracted by magnetic field - This property is known as anti ferromagnetism.

Radius ratio → It is the ratio of radius of the cation to the radius of anion.

Mathematically

$$\text{Radius ratio} = \frac{\text{radius of cation}}{\text{radius of anion}}$$

Radius ratio determines the geometry of the crystal.

Radius ratio	Coordination no.	Geometry of crystal
0.155 - 0.225	3	Trigonal planar
0.225 - 0.414	4	Tetrahedral
0.414 - 0.732	6	Octahedral
0.732 - 1	8	Cube