

Solid State

→ On the basis of amount of kinetic energy present in constituent particles (It may be atoms, ions or molecules) matter can be classified into three. They may be solids, liquids and gases.

→ In solid state constituent particles have minimum kinetic energy. Therefore they show maximum interaction. Because of this they are closely packed and they have definite shape.

classifications of solids.

On the basis of arrangement of constituent particles, solids can be classified into two. They are, Crystalline solids and Amorphous solids.

Crystalline Solids

A solid in which constituent particles are arranged in a regular, repeating, alternating manner.

Amorphous Solids

A solid in which constituent particles are arranged in an irregular, random manner.

Amorphous solids are pseudosolids or supercooled liquids.

Difference b/w crystalline and amorphous solids.

Crystalline solid	Amorphous solid
It has a long range order	It has a short range order
It gives a regular cleavage when we cut	It gives an irregular cleavage when we cut
It is Anisotropic (shows different physical properties in different directions)	It is isotropic (shows same physical properties in all directions)
It has a sharp melting point	It has a range melting point.
NaCl, Diamond, Naphthalene.	Plastic, Rubber, glass.

classification of crystalline solid

On the basis of nature of constituent particles crystalline solids can be classified into four. They are ionic solids, covalent solids, Molecular solids and Metallic solids.



Name	Constituent Particle	attractive force	Properties	Examples
Ionic Solid	ions	ionic bond	Hard, Brittle, High melting, Poor conductors	NaCl, KCl, LiCl etc.
covalent Solid	atoms	covalent bond	Hard High melting, Poor conductors	Diamond, Graphite, Quartz, Silica, etc.
<p>Note: Here graphite is an exceptional, which is a good conductor due to its layered structure.</p>				
Molecular Solids	Molecules	inter molecular force or Van der Waal's force of attraction	Soft, low melting, Poor conductors	ice, Wax, Camphor, dry ice, Naphthalene, solid I_2 , solid NH_3 , solid H_2O
Metalllic Solid	cations and mobile electrons	Metalllic bond	Soft-hard, low melting-high melting good conductors	all metals.

classification of molecular solids

On the basis of nature of intermolecular force molecular solids can be classified into three. They are polar, non-polar, and Hydrogen bonded molecular solids.

1. Polar Molecular Solids

Molecular solids in which molecules are held together by dipole-dipole interaction.

eg: - Solid HCl

2. Non - Polar Molecular Solid

Molecular solid in which molecules are held together by London dispersion force.

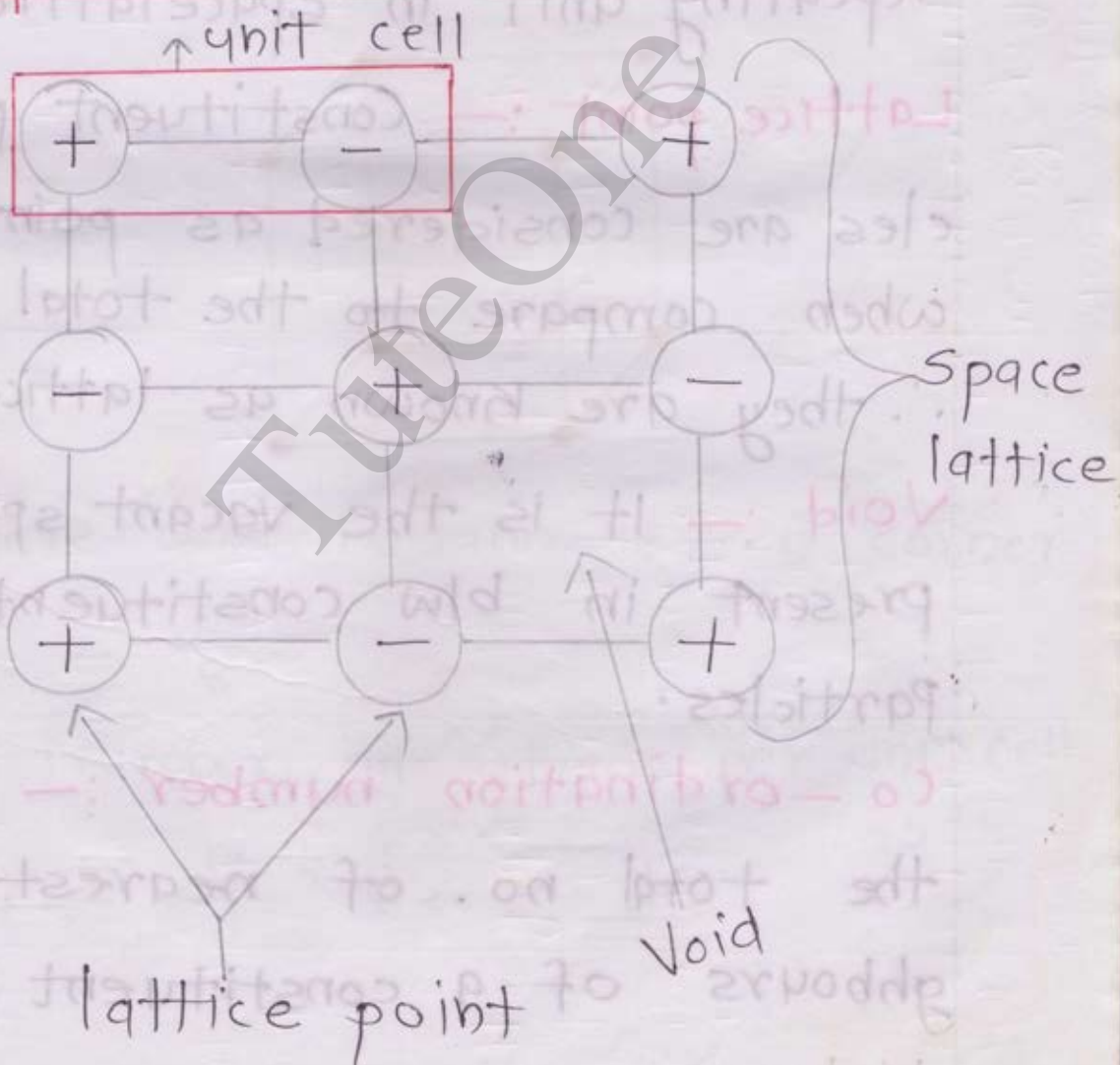
eg: - Solid iodine.

3. Hydrogen Bonded Molecular Solid

Molecular solid in which molecules are held together by hydrogen bond.

eg:- ice.

Space lattice and Unit cell



Space lattice :- Regular, Repeating and alternating arrangement of constituent particles in 3 dimensional space.

Unit cell :- It is the smallest repeating unit in space lattice

Lattice point :- Constituent particles are considered as points when compare to the total lattice. \therefore they are known as lattice point

Void :- It is the vacant space present in b/w constituent particles.

Co-ordination number :- It is the total no. of nearest neighbours of a constituent particles.

IMP. Cubic lattices and no. of atoms
per unit cells.

1. Simple cube (Primitive lattice)

Here the constituent particles are arranged at every corners of a cube.



Here contribution of a corner

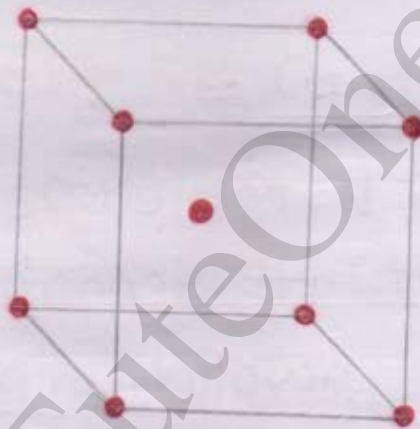
$$= \frac{1}{8}$$

\therefore Number of atoms per unit cell

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

2. B.c.c. (Body centered cube)

Here the Particles are arranged at every corners and centre of the body.



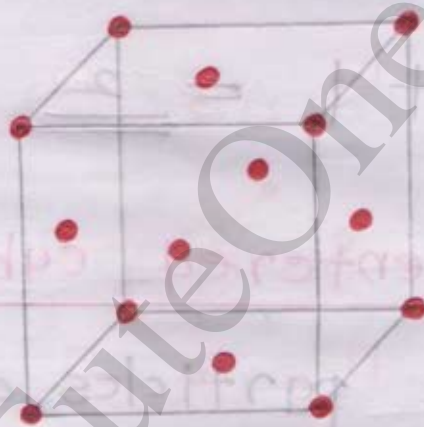
Contribution of body centre
= 1

$$\therefore \text{number of atoms per unit cell} = \left(\frac{1}{8} \times 8 \right) + 1 = \underline{\underline{2}}$$

3. F.C.C. (Face centered cube)

The particles are arranged at every corners and centre of the faces.

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



Here the contributions of a face centre = $\frac{1}{2}$

\therefore No. of atoms per unit cell

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

$$= 1 + 3 = \underline{\underline{4}}$$

4. End centered cube



Here the particles are arranged at every corners and two opposite face centres.

No. of atoms per unit cell

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

$$= 1 + 1 = \underline{\underline{2}}$$

5. Edge centered cube



Here the particles are arranged at every corners and centre of the edges.

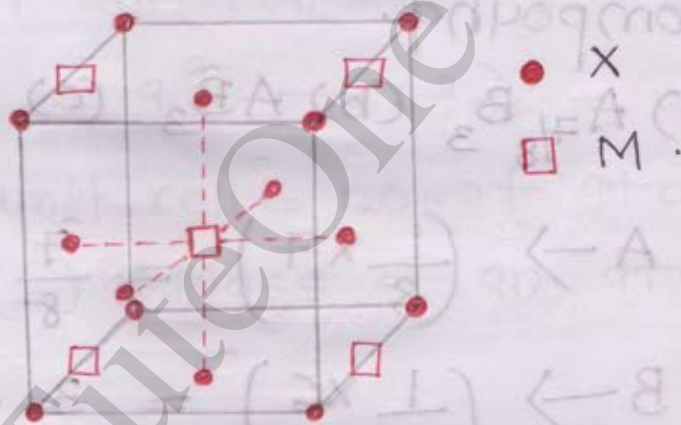
contribution of an edge

$$\text{centre} = \frac{1}{4} \cdot \left(8 \times \frac{1}{8} \right)$$

\therefore No. of atoms per unit cell

$$= \left(12 \times \frac{1}{4} \right) + \left(\frac{1}{8} \times 8 \right) = 3 + 1 = \underline{\underline{4}}$$

Q A compound M_pX_q has FCC arrangement of X. Its unit cell structure is given below. Give the empirical formula of the compound.



- (a) MX (b) MX_2 (c) M_2X (d) M_5X_{14}

An: $M \rightarrow 1 + \left(\frac{1}{4} \times 4\right) = 1 + 1 = \underline{2}$

$X \rightarrow \left(\frac{1}{8} \times 8\right) + \left(\frac{1}{2} \times 6\right) = 1 + 3 = \underline{4}$

Molecular formula = M_2X_4

\therefore Empirical formula = MX_2

\therefore An: (b)

Q A solid in which 'A' atoms are arranged at corners and B atoms are arranged at the face centered. One of the A atom is missing from one corner of the cube. Then calculate the formula of the compound.

(a) $A_{7/8}B_3$ (b) AB_3 (c) AB_4 (d) A_7B_{24}

An: $A \rightarrow \left(\frac{1}{8} \times 7 \right) = \frac{7}{8}$

$B \rightarrow \left(\frac{1}{2} \times 6 \right) = 3$



An: (d)

IMP.

Density of unit cell.

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

— (1)

Volume of unit cell having edge length 'a' = a^3 — (2)

Mass of unit cell = no. of atoms per unit cell (z) \times Mass of an atom.

Here

Mass of an atom = $\frac{\text{atomic mass (M)}}{\text{avogadro no. } (N_A)}$

\therefore Mass of unit cell = $\frac{zM}{N_A}$ — (3)

Substitute (2) and (3) in eq. (1)

density of unit cell,

$$\rho = \frac{zM}{a^3 N_A}$$

Q Calculate the density of a B.C.C unit cell having edge length 400 pm. and atomic mass 100 g/mol.

(a) 3.144 g/cm³

(b) 5.188 g/cm³

(c) 7.144 g/cm³

(d) 9.188 g/cm³

Ans:

$$Z = 2$$

$$M = 100$$

$$a = 400 \times 10^{-10}$$

$$\rho = \frac{ZM}{a^3 N_A}$$

$$= \frac{2 \times 100}{(400 \times 10^{-10})^3 \times 6.022 \times 10^{23}}$$

$$\rho = 9.188 \text{ g/cm}^3$$

$$\rho = 9.188 \text{ g/cm}^3$$

$$= 200$$

$$64000000 \times 10^{-30} \times 6.022 \times 10^{23}$$

$$= \frac{2}{32} \times 6.022 \times 10^{-30} \times 10^{23} \times 10^4$$

$$= \frac{1}{32 \times 6.022 \times 10^{-3}}$$

$$= \frac{1}{192 \times 10^{-3}}$$

$$= \frac{1000}{192}$$

$$= 5.188 \text{ g/cm}^3$$

An: (b)

$$\begin{array}{r} 32 \times \\ 6 \\ \hline 192 \end{array}$$

$$\begin{array}{r} 192 \overline{) 1000} \\ 384 \\ \hline 1144 \end{array}$$

$$\begin{array}{r} 192 \overline{) 1000} \\ 384 \\ \hline 1252 \end{array}$$

$$\begin{array}{r} 192 \overline{) 1000} \\ 384 \\ \hline 768 \\ \hline 960 \end{array}$$

Q How many unit cells are present in an ideal crystal of NaCl of mass 1 g. NaCl has FCC structure.

(a) 1.35×10^{21} unit cells

(b) 2.57×10^{21} unit cells

(c) 3.46×10^{21} unit cells

(d) 9.35×10^{21} unit cells.

Ans.

$$f = \frac{ZM}{a^3 N_A}$$

$$M = \frac{f a^3 N_A}{Z}$$

$$\text{NaCl} \rightarrow 23 + 35.5 = \underline{\underline{58.5}}$$

58.5 g NaCl contains 6.022×10^{23} atoms

1 g NaCl contains $\frac{6.022 \times 10^{23}}{58.5 \times 4}$ atoms

1 g NaCl atoms =

$$\text{Containing unit cells} = \frac{6.022 \times 10^{23} \times 2}{(58 + \frac{1}{2}) \times 4}$$

$$= \frac{1.5 \times 6.022 \times 10^{23} \times 2}{117 \times 4}$$

$$= \frac{1.5 \times 2 \times 10^{23}}{117}$$

$$= \frac{3 \times 10^{23}}{117}$$

$$117 \overline{) 300} \\ \underline{234} \\ 66$$

$$= 0.02 \times 10^{23}$$

$$= \underline{\underline{2.57 \times 10^{21}}}$$

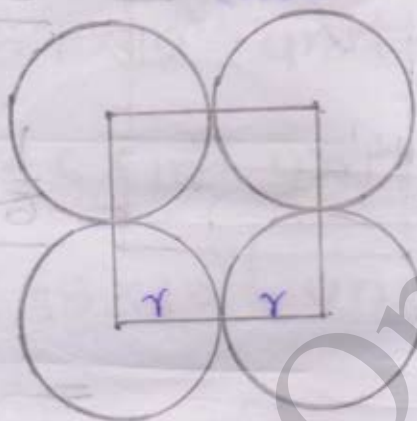
An: (b)

unit cell $\times 4$ = atoms
unit cell = $\frac{\text{atoms}}{4}$

1 FCC \rightarrow 4 atoms \rightarrow 1 unit cell
2 FCC \rightarrow 8 atoms \rightarrow 2 unit cells

Relationship b/w radius and edge length

1. Simple cube



$$a = 2r$$

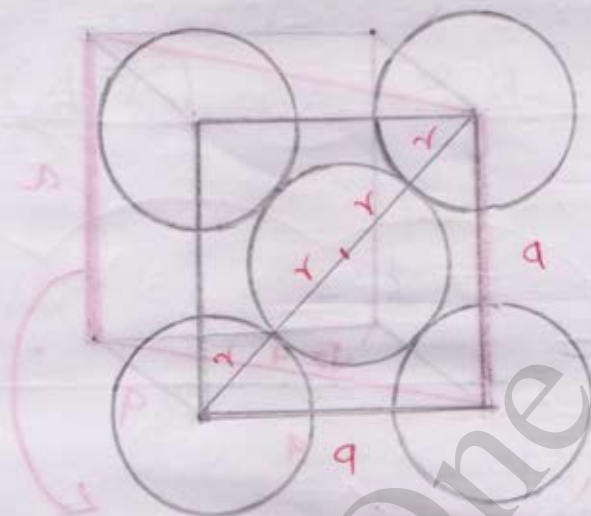
$$2r = a$$

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

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

Ans: (b)

2. F.C.C.



$$(4r)^2 = a^2 + a^2$$

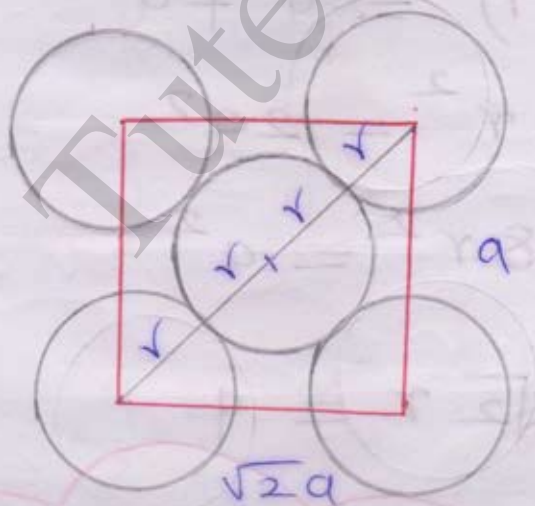
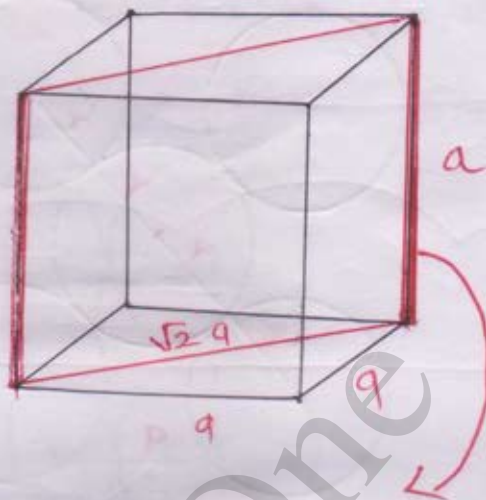
$$16r^2 = 2a^2$$

$$8r^2 = a^2$$

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

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

3. B. C. C.



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

$$(4r)^2 = a^2 + (\sqrt{2}a)^2$$

$$(4r)^2 = a^2 + 2a^2$$

$$(4r)^2 = 3a^2$$

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

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

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

Note

Face diagonal of a cube = $\sqrt{2}a$.

Body diagonal of a cube = $\sqrt{3}a$.

Packing efficiency or Packing fraction.

It is the percentage of available space occupied by spheres.

$$P.E = \frac{Z \times \left(\frac{4}{3} \pi r^3 \right) \times 100}{a^3} \%$$

Here,

$Z \rightarrow$ no. of atoms per unit cell

$\frac{4}{3} \pi r^3 \rightarrow$ volume of a sphere or atom having radius 'r'

$a^3 \rightarrow$ volume of a cube or unit cell

Packing efficiency of Simple cube

$$P.E = \frac{Z \times \left(\frac{4}{3} \pi r^3 \right) \times 100}{a^3} \%$$

Here,

$$Z = 1$$

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

Then

$$P.E = \frac{1 \times \frac{4}{3} \pi \left(\frac{a}{2} \right)^3 \times 100}{a^3}$$

$$= \frac{4 \pi \cdot \frac{a^3}{8} \times 100}{3 \times a^3 \times 8}$$

$$= \frac{\pi}{6} \times 100$$

$$= 52.3 \%$$

Packing efficiency of B.C.C.

$$P.E = \frac{Z \times \left(\frac{4}{3} \pi r^3 \right) \times 100}{a^3}$$

Here

$$Z = 2$$

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

Then

$$P.E = \frac{2 \times \frac{4}{3} \pi \left(\frac{\sqrt{3}a}{4} \right)^3 \times 100}{a^3}$$

$$= \frac{2 \times 4 \times \pi \times \cancel{3} \sqrt{3} \times \cancel{a^3} \times 100}{\cancel{3} \times \cancel{4} \times \cancel{a^3}}$$

$$= \frac{100 \pi}{\cancel{8}}$$

$$\frac{1}{\sqrt{2}}$$

$$= \frac{11}{8} \times 100 \times \sqrt{3}$$

$$\frac{314}{8}$$

$$= \frac{314 \times \sqrt{3}}{8}$$

$$\frac{50}{25}$$

$$= 68\%$$

Packing efficiency of f.c.c.

$$P.E = \frac{Z \times \left(\frac{4}{3} \pi r^3 \right) \times 100}{a^3}$$

Here,

$$Z = 4$$

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

Then,

$$P.E = \frac{4 \times \frac{4}{3} \pi \left(\frac{a}{2\sqrt{2}} \right)^3 \times 100}{a^3}$$

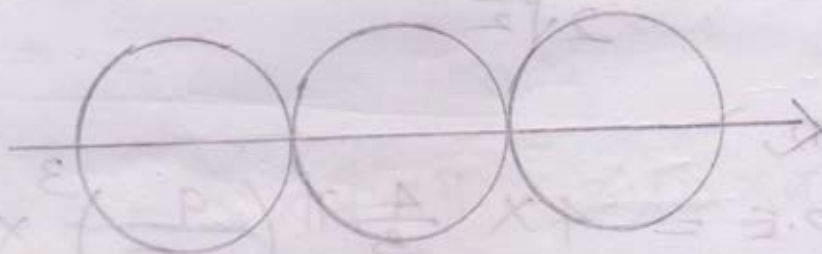
$$= \frac{4 \times 4 \times \pi \times a^3 \times 100}{3 \times a^3 \times 16\sqrt{2}}$$

$$= \frac{\pi}{3\sqrt{2}} \times 100$$

$$= \underline{\underline{74\%}}$$

close packing in crystalline solid.

1. one dimensional close packing.



Here the adjacent spheres are touching each other in a single row.

co-ordination number = 2.

Q. Two Dimensional close packing

It is of two types;

1. SCP (Square close packing)

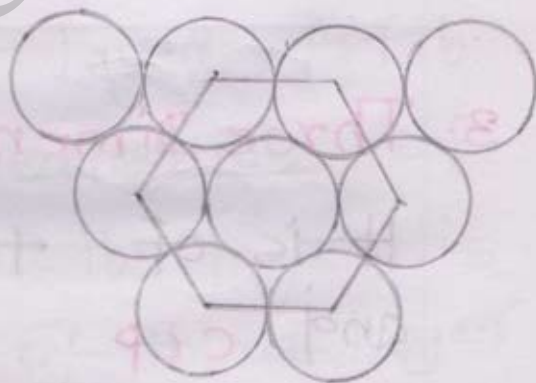
and

2. HCP (Hexagonal close packing)

SCP



HCP



Here spheres are arranged in a vertical and horizontal manner.

Here spheres present in every second layer is placed in the depression b/w two adjacent spheres in

the first layer	
Square pattern repeats here.	Hexagonal pattern repeats here.
Square voids are present here.	Triangular voids are present here.
co-ordination number = 4	co-ordination number = 6.
less efficient	High efficient

3. Three Dimensional close packing.
It is of two types. HCP and CCP

1. HCP (Hexagonal close packing)

→ ABAB..... type packing.

ie; Third layer is the repetition of first layer, fourth

layer is the repetition of second layer and so on.

→ Here spheres are placed above alternate type voids.

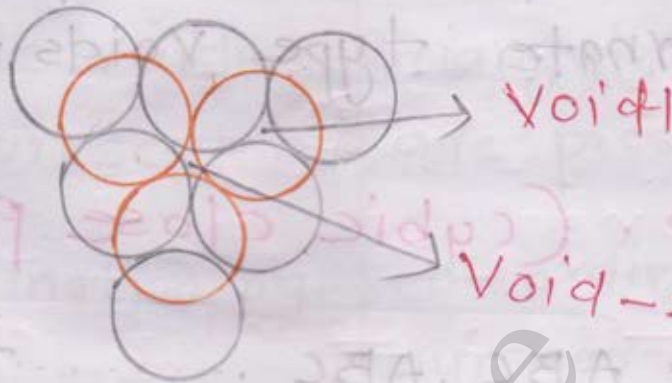
∴ c.c.p. (cubic close packing)

→ Here ABC, ABC ... type packing

ic; fourth layer is the repetition of first layer, fifth layer is the repetition of second layer, sixth layer is the repetition of third layer and so on.

★ → Here spheres are placed above same type voids.

Voids in three dimensional close packing.



Void-1

Void-2



Tetrahedral
Void

It is the void
present in b/w



Octahedral
Void

It is the void
present in b/w

4 adjacent
spheres.

no. of tetrahedral void is
double the no.
of spheres.

Six adjacent
spheres.

no. of octahedral void is
equal to no.
of spheres.

Note :-

consider a solid having 'n'
spheres,

no. of octahedral void = n

no. of tetrahedral void = 2n

→ Co-ordination number in 3-D
close packing

Co-ordination number of a sphere
in 3-D close packing = 12

6 - its on layer, 3 - layer

below and 3-layer above)

∴ Both HCP and CCP are equally efficient.

Their packing efficiency = 74%

∴ No. of atoms per unit cell in HCP = CCP = FCC = 4

Q Sodium metal crystallises in a BCC with a unit cell edge of 4.29 \AA . The radius of sodium atom is approximately

(a) 1.86 \AA . (b) 3.22 \AA

(c) 5.72 \AA (d) 0.93 \AA

JEE
-2015

An:

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

$$= \sqrt{3} \times 1.07$$

$$= 1.73 \times 1.07$$

$$= \underline{\underline{1.86 \text{ \AA}}}$$

$$\begin{array}{r} 1.73 \times \\ 1.07 \\ \hline 1.8511 \end{array}$$

An: (a)

Properties of Solids.

1. Magnetic property.

On the basis of their magnetic behaviour, solids can be classified into five. They are paramagnetic, Diamagnetic, ferromagnetic, ferimagnetic and antiferromagnetic.

1. Paramagnetic :

Solid which are attracted towards external magnetic field due to the presence of unpaired electrons.

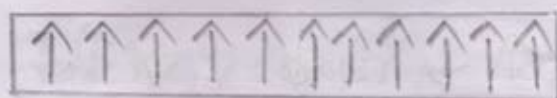
eg: - Fe^{3+} , Cr^{3+} , Cu^{2+}

2. Diamagnetic

Solid which do not attracted towards external magnetic field due to the absence of unpaired electrons.

eg: - NaCl ,

3. Ferro Magnetic : $\mu \gg \mu_0$



Here magnetic moments are aligned in one direction. \therefore they show maximum magnetism.

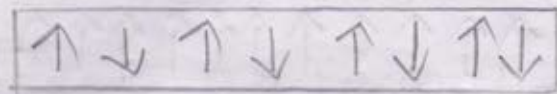
Ferromagnetism is extreme case of paramagnetism.

eg:- Fe, Co, Ni

Note:-

Ferromagnetic substances show magnetism even in the absence of external magnetic field, but paramagnetic substances show magnetism only in the presence of external magnetic field.

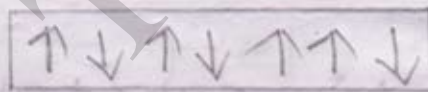
4. Anti-ferro magnetic.



Here equal no. of magnetic moments are aligned in equal and opposite direction. \therefore their net magnetic moment equal to zero.

eg:- MnO , MnO_2

5. Ferri magnetic.



Here unequal no. of magnetic moments are aligned in equal and opposite direction.

\therefore slight magnetism remains there.

eg:- Fe_3O_4

→ Electrical Properties

On the basis of their electrical behaviour, solids can be classified into three.

They are, conductors, insulators and semiconductors.

Electrical property can be explained by using Band theory.

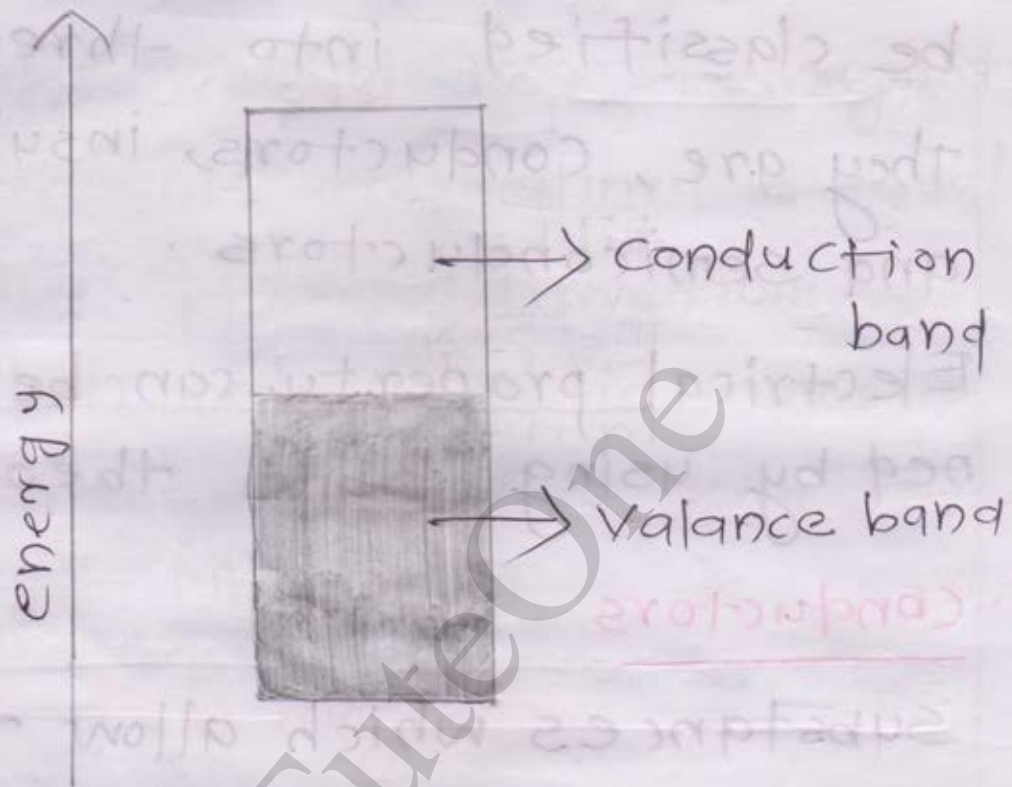
1. Conductors

Substances which allow the easy passage of electricity through them.

According to band theory, in conductors there is no energy difference b/w valence band and conduction band.

∴ Valence electrons can always

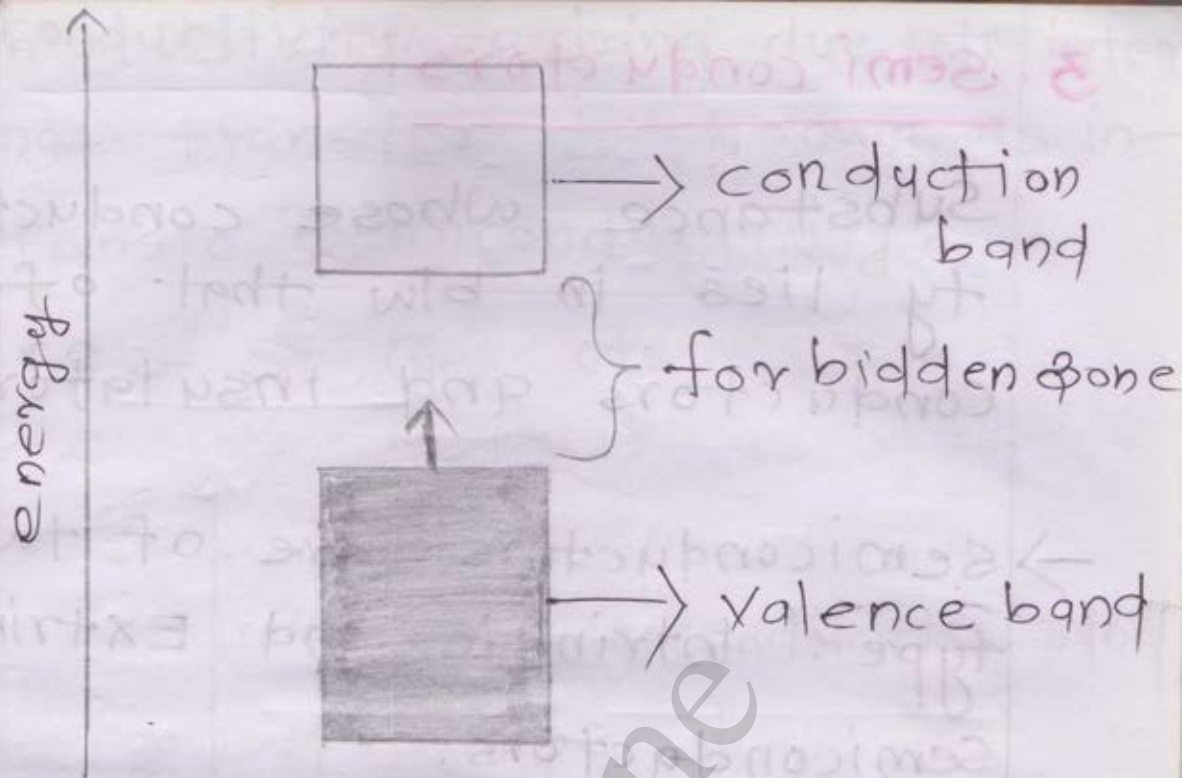
goes to conduction band and they can show good conductivity.



eg: — metals.

Q. Insulator

Substances which do not allow the passage of electricity through them.



Here the energy difference is b/w valence band and conduction band (for forbidden zone) is very high \therefore Vacant conduction band is not available for valance electrons.

eg:— charcoal.

3. Semiconductors.

Substance whose conductivity lies in b/w that of conductors and insulators.

→ Semiconductors are of two type. Intrinsic and Extrinsic Semiconductors.

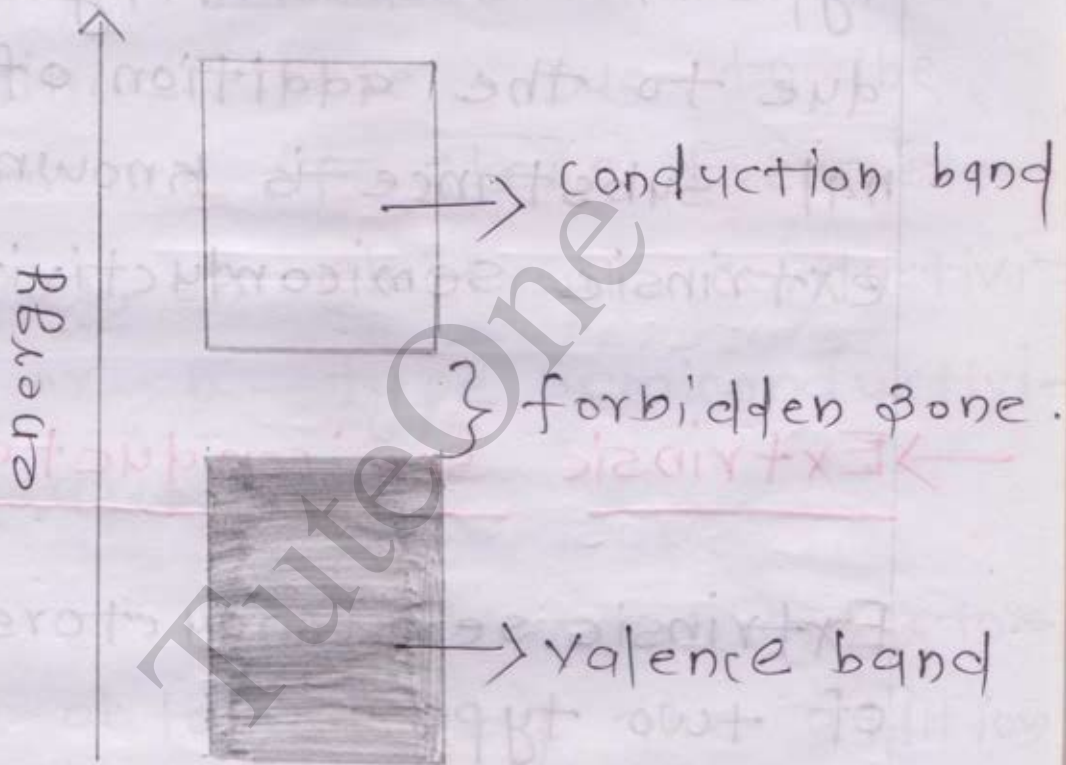
→ Intrinsic Semiconductors.

Here the energy difference in b/w valance band and conduction band is low.

∴ by absorbing thermal energy valance electrons can go to vacant conduction band. This type of semi

conductivity arising due to internal transfer is known as intrinsic semiconductor.

eg:— Si, Ge etc.



Note:—

Intrinsic semiconductors work only at high temperature.

∴ to get permanent semiconductor we can add some

external substance to the crystalline of intrinsic semiconductors. This process is known as Dopping. This type of conductivity arising due to the addition of external substance is known as extrinsic semiconductor.

→ Extrinsic Semiconductors

Extrinsic semiconductors are of two type.

n-type and p-type Semiconductors.

n-type semiconductors are obtained by the addition of a 15th group element

like P, As to the crystalline of 14th group element like Si, Ge. At that time after the formation of 4 covalent bond 1 excess electron remains there. Due to the presence of these free electrons, an electronic conductivity or n-type semiconductivity arises.

P-type semiconductors are obtained by the addition of a 13th group element like Al, Ga to the crystalline of 14th group element. After the formation of 3 covalent bonds, an electron deficient bond or a hole remains there.

Due to the presence of this hole a hole conductivity or p-type semiconductivity arises.

Note: —

Curie temperature — The temperature at which ferro, ferri and Anti-ferro magnetic substances shows paramagnetism.

→ Stoichiometric and Non-stoichiometric compound.

Stoichiometric compounds are compounds in which the ratio of exist in b/w cations and anions is same

as that expected from their chemical formula.

Non-stoichiometric compounds are compounds in which the ratio exist in b/w cations and anions is different as that expected from their chemical formula.

eg:- FeO

In FeO, the composition of Fe varies from 0.84 to 0.96.

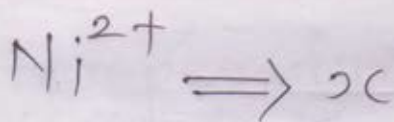
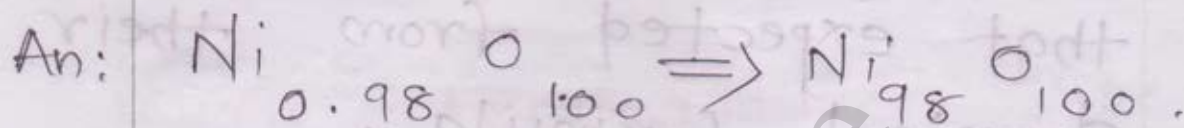
VO

In VO the composition of O_2 varies from 0.6 to 1.3.

Q
NCERT
(16)

Analysis shows that Nickel oxide has formula $\text{Ni}_{0.98}\text{O}_{1.00}$

What fractions of Nickel exist as Ni^{2+} and Ni^{3+} ions.



$$2x + 3(98 - x) + -2 \times 100 = 0$$

$$2x + 294 - 3x - 200 = 0$$

$$94 - x = 0$$

$$\underline{\underline{94 = x}}$$

$$\therefore \text{Ni}^{2+} = 94$$

$$\text{Ni}^{3+} = 98 - 94 = \underline{\underline{4}}$$

$$\text{Fraction of } \text{Ni}^{3+} = \frac{4}{98} \times 100$$

$$= \underline{\underline{4.08\%}}$$

$$\text{fraction of } \text{Ni}^{2+} = \frac{94}{98} \times 100$$

$$= \underline{\underline{95.92\%}}$$

✓
(25) Q If NaCl is doped with 10^{-3} mol % of SrCl_2 . What is the concentration of cation vacancies. space.

An: NaCl.

$$\text{SrCl}_2 = 10^{-3} \text{ mol \%}$$

$$= \frac{1}{1000} \text{ mol \%}$$

one Sr^{2+} can replace 2 Na^+ ions, at that time 2 vacant sites are formed. where one will be occupied by Sr^{2+} .
 \therefore one vacant site remains there.

Concentration of cation vacancy

$$n_v = \frac{1 \times 6.022 \times 10^{23} \times 10^{-3}}{1000}$$
$$= 6.022 \times 10^{18}$$

→ Defects or imperfections
in crystalline solid.

Any type of deviation from the regular, repeating and alternating arrangement of crystalline solid is known as

defect or imperfection.

→ Defects are generally point defects or atomic imperfections.

→ Point defect may be due to,

1. Missing of a constituent particles from its normal lattice site and

2. Migration of a constituent particles from its normal lattice site into void.

→ Point defects are of two type.

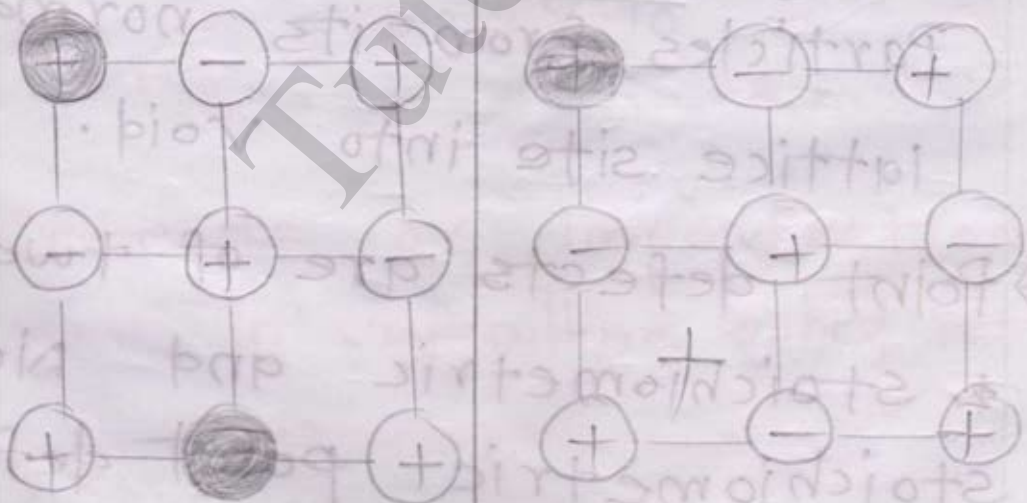
* Stoichiometric and Non-stoichiometric point defects.

Stoichiometric point defects

The defect which do not disturb the stoichiometry of a compound.

Stoichiometric point defects are of two type, Schottky defect and Frenkel defect.

IMP. Schottky defect Frenkel defect



Here equal no. of cations and anions are missing. Here an ion migrate from its normal lattice site to an interstitial site.

missing from their normal lattice site, leaving behind a pair of holes.

crystals having equal size of cations and anions shows this defect — crystals having different size of cations and anions shows this defect.

crystals having high coordination number shows this defect — crystals having less coordination number shows this defect.

Density decreases due to this defect — Density remains same even after the defect.

eg: — NaCl, KCl
AgBr

AgCl, AgBr,
ZnS.

Note

I AgBr shows both Schottky defect and Frenkel defect.

II In non-ionic crystals, Vacancy defect and interstitial defect are observed as stoichiometric point-defects.

1. Vacancy defects.

In certain crystals lattice sites are observed as vacant site. Such defects are known as vacancy-defect.

2. Interstitial defect.

In certain crystals atoms are present in interstitial

Sites. Such atoms are known as interstitials and this defect is known as interstitial defect.

→ Non-stoichiometric point defect

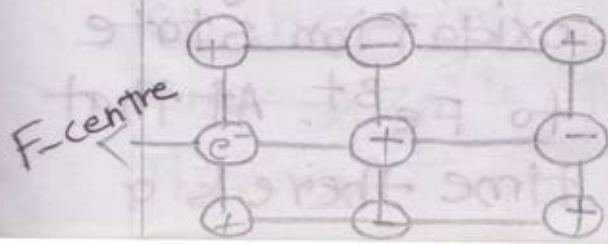
The defect which disturbs the stoichiometry of a compound.

Non-stoichiometric point defects are of two types.

Metal excess and Metal deficiency defects.

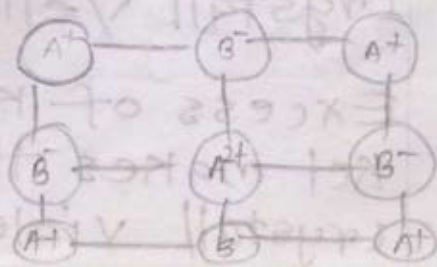
Metal excess defect.

1. due to anion vacancy.



Metal deficiency defect.

due to cation vacancy.



Here an anion missing from its normal lattice site, living behind a hole. which will be occupied by a electron nearest neighbour to maintain electrical neutrality. This site is responsible for the colour of the compound. \therefore this site is known as F-centre.

(Favour centre)

eg:- Excess of Na in NaCl makes the crystal yellow.

Excess of K in KCl makes the crystal violet.

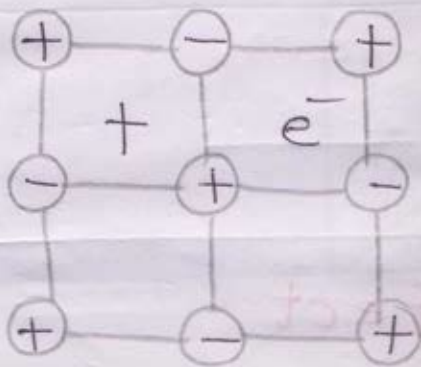
Here a cation missing from its normal lattice site, living behind a hole. At that time nearest neighbour change its oxidation state to maintain electrical neutrality.

eg:- Fes.
(Iron pyrites).

If a Fe^{2+} ion missing from Fes crystal, two nearest Fe^{2+} change their oxidation state to Fe^{3+} . At that time there is a

Excess of Li in continuous e^- ex-
 LiCl makes the change occur in
 crystal pink. b/w Fe^{2+} and
 Fe^{3+} . \therefore Compound shines like

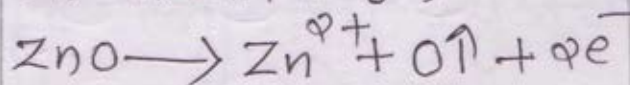
2. Due to the presence of extra cation.



gold in presence of light. Because of this FeS is known as fool's gold.

Here an extra cation present in void, the nearest void will be occupied by electron to maintain electrical neutrality
 eg: - ZnO

on heating,



This Zn^{2+} and $2e^-$

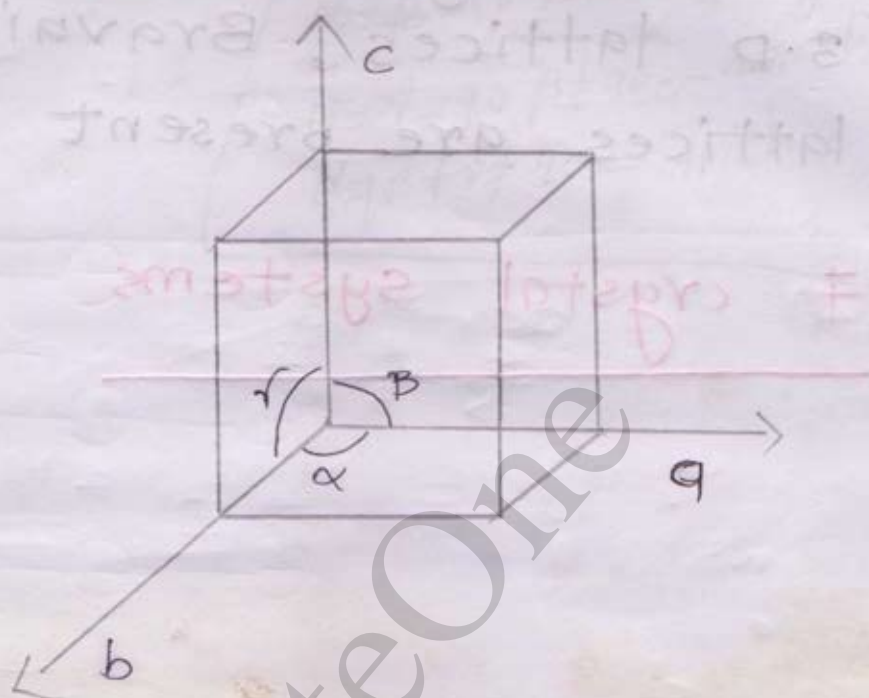
are trapped in voids. Due to the presence of these two free electron ZnO becomes yellow in colour.

→ Impurity Defect

It is the defect arising due to the presence of external impurities.

This defect arising due to the action of certain chemical process like dopping.

→ Bravais lattices and crystal Systems



Generally unit cells having cubic shape. At that time

$$a = b = c \text{ and } \alpha = \beta = \gamma = 90^\circ.$$

Certain crystals shows deviation from these angle and side length relationship. \therefore total 7 crystal system are present. In which constituent particles

are arranged at the corners, edge centres, face centres and Body centre. \therefore 14 3.D lattices, Bravais's lattices are present.

7 crystal systems

Crystal System	Unit Cell dimensions		Examples
1. Triclinic	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90^\circ$	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, $\text{K}_2\text{Cr}_2\text{O}_7$, H_3BO_3
2. Monoclinic	$a \neq b \neq c$	$\alpha = \gamma = 90^\circ; \beta \neq 90^\circ$	Monoclinic sulphur, $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$
3. Orthorhombic	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	Rhombic sulphur, KNO_3 , BaSO_4
4. Trigonal / rhombohedral	$a = b = c$	$\alpha = \beta = \gamma \neq 90^\circ$	CaCO_3 , HgS
5. Cubic	$a = b = c$	$\alpha = \beta = \gamma = 90^\circ$	NaCl, diamond, ZnS, KCl
6. Tetragonal	$a = b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	TiO_2 , SnO_2 , CaSO_4
7. Hexagonal	$a = b \neq c$	$\alpha = \beta = 90^\circ; \gamma = 120^\circ$	Mg, ZnO, CdS, graphite

$$a = b = c$$

C a R

$$a = b \neq c$$

H a T

$$\alpha = \beta = \gamma = 90^\circ \rightarrow \text{COT}$$

$$\alpha = \beta = \gamma \neq 90^\circ \rightarrow \text{Rhombic}$$

$$\alpha = \beta = 90^\circ, \gamma \neq 120^\circ = \text{Hexagonal}$$

$$\alpha = \beta = 90^\circ, \gamma \neq 90^\circ = \text{monoclinic}$$

$$\alpha \neq \beta \neq \gamma \neq 90^\circ = \text{Triclinic}$$

$$a \neq b \neq c$$

T O M