



# **Ionic solids**

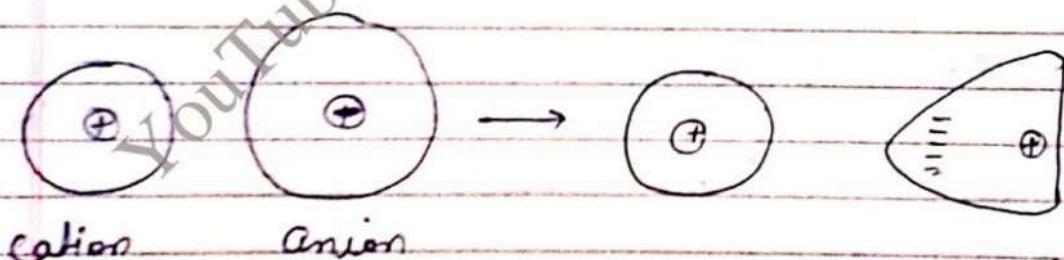
# IONIC SOLID

Polarisation  $\rightarrow$  During ionic bond formation cation and anion comes close to each other. In this situation cation distort the  $e^-$  cloud of anion.

This phenomena is known as polarisation.

The tendency of cation to distort  $e^-$  cloud of anion is known as polarising power of cation.

Due to polarisation sharing of  $e^-$ 's of both cation and anion take place. Hence covalent character arises in a ionic bond.



polarisation & covalent character

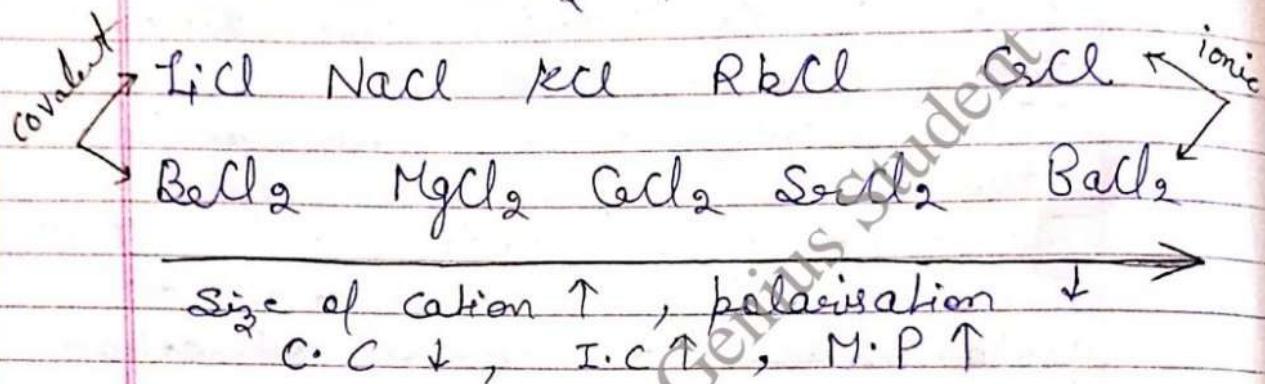
-: Fajan's Rule :-

Date \_\_\_\_\_  
Page \_\_\_\_\_

factors affecting polarisation :-

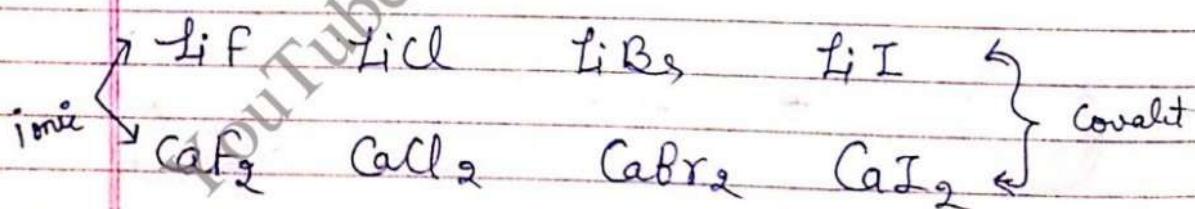
① Size of Cation

$$\text{polaris}^n \propto \frac{1}{\text{Size of cation}} \propto \text{covalent char.}$$



② Size of Anion

$$\text{polarisation} \propto \text{Size of anion} \propto \text{C. characters}$$



Size of anion ↑, Polarisation ↑, C.C. ↑  
I.C. ↓, M.P. ↓

\* AgCl → white colour  
AgBr → light yellow  
AgI → dark yellow

Size of anion ↑  
Polaris<sup>n</sup> ↑  
C.C. ↑  
color intensity ↑

Teacher's Signature:

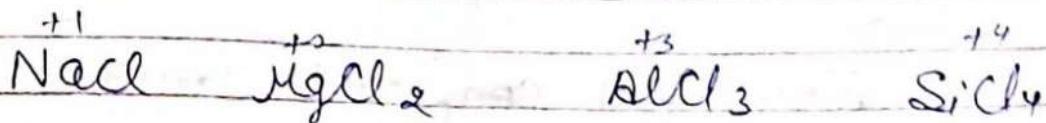
Scanned with CamScanner

Scanned with CamScanner

Scanned with CamScanner

### ③ Charge on Cation

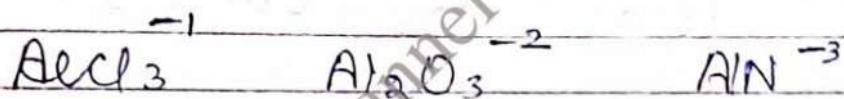
polaris<sup>n</sup>  $\propto$  charge on cation  
 $\propto$  C.C



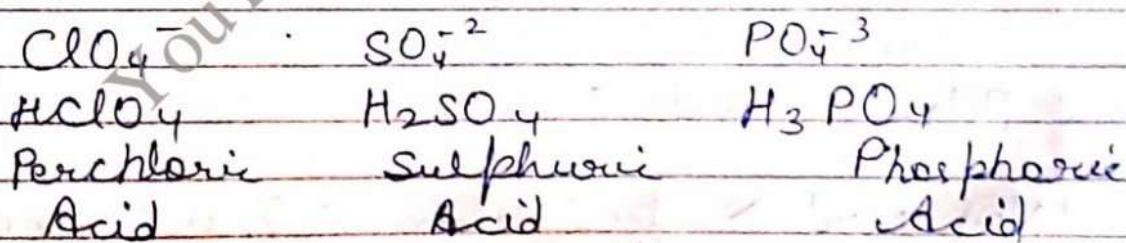
Charge on cation ↑, polaris<sup>n</sup> ↑  
C.C ↑, M.P. ↓

### ④ Charge on Anion

polaris<sup>n</sup>  $\propto$  charge on anion  
 $\propto$  C.C



charge on anion ↑, polarization ↑  
Covalent character ↑



charge on anion ↑, polaris<sup>n</sup> ↑,  
C.C ↑, ionic tendency ↓,  
H<sup>+</sup> releasing tendency ↓, acidic  
Nature ↓

## ⑤ Electronic config' of cation

On the basis of electronic config' of cation are of 3 type

### (1) Inert gas config' cation

Cation which have  $8 e^-$  in their valence shell.

Eg  $\rightarrow Na^+, K^+, Li^+, Rb^+, Ba^{+2}, Mg^{+2}$   
 $V.S = 8e^- \quad ns^2 \quad np^6$

### (2) Pseudo inert gas config' cation

Eg  $\rightarrow Cu^+, Ag^+, Zn^{+2}, Cd^{+2}, Cr^{+3}$   
 $V.S = 18 e^- \quad ns^2 \quad np^6 \quad nd^{10}$

### (3) Non inert gas config' cation

Eg  $\rightarrow Pb^{+2}, Tl^+, Hg$   
no of ~~e-~~  $= 18 + 2e^-$   
 $ns^2 \quad np^6 \quad nd^{10} \quad (n+1)S^2$

Polaris'n and C.C order

Non-inert  $>$  p. I cation  $>$  Transition cation

NaCl

$Na^+$

Fionic comp'd

CuCl

$Cu^+$

Covalent comp'd

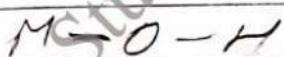
## Tonic potential

Ratio of charge on cation to the size of cation is known as ionic potential.

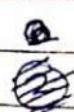
$\phi$  & polarization & C.C

Application of  $\phi$  :-

① Nature of Oxide



if a metal ion have higher value of  $\phi$  then its oxide will be acidic in nature becoz metal Oxygen bond ( $\text{M}-\text{O}$ ) will have more covalent nature which will not dissociate easily.



if a metal ion have low value of  $\phi$  then its oxide will be basic in nature becoz  $\text{M}-\text{O}$  will have ionic nature which will dissociate easily.

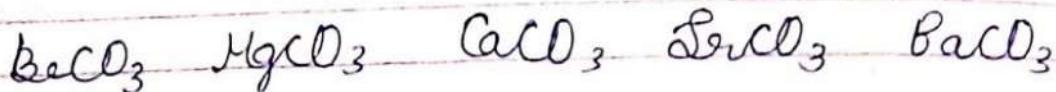
② On Decreasing value of  $\phi$

③ Thermal stability of Metal Carbonate

On increasing value of  $\phi$  for any metal carbonate  $\text{MO CO}_3$  ( $\text{M}-\text{O}-\text{CO}_3$ )

Teacher's Signature.....

H-O bond have more O.C. hence O-H bond become more strong, and  $\text{CO}_2$  gas releases easily.



$\phi \downarrow$ , polaris<sup>n</sup>  $\downarrow$ , Thermal decom<sup>n</sup>  $\downarrow$   
Thermal stability  $\uparrow$

Acc to Caridge

$\phi < 2.2$  Basic oxide

$\phi = 2.2$  to  $3.2$  Amphoteric

$\phi > 3.2$  Acidic oxide

Radius ratio and coordination no.

The ratio of radius of cation to that of anion is known as radius ratio.

$$\text{Radius ratio} = \frac{r_+}{r_-}$$

coordination no  $\rightarrow$  The no of ions which surrounds an oppositely charged ion is known as coordination no.

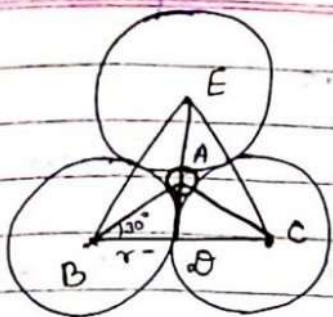
① Radius ratio for tetrahedral voids / site :-

$$C.N = 3$$

Teacher's Signature

small circle  $\rightarrow$  cation ( $r_+$  radius)

Date \_\_\_\_\_  
Page \_\_\_\_\_



A trigonal site is formed when the 3 anions lie at the vertex of equilateral triangle.

And cation occupies the trigonal side.

$$BC = CE = BE = 2r_-$$

Right angle triangle  $BDA$

$$\cos(\angle ABD) = \frac{BD}{AB} = \frac{r_-}{r_- + r_+}$$

$$\cos 30^\circ = \frac{\sqrt{3}}{2} = \frac{r_-}{r_- + r_+}$$

$$\frac{r_+}{r_-} = 0.155$$

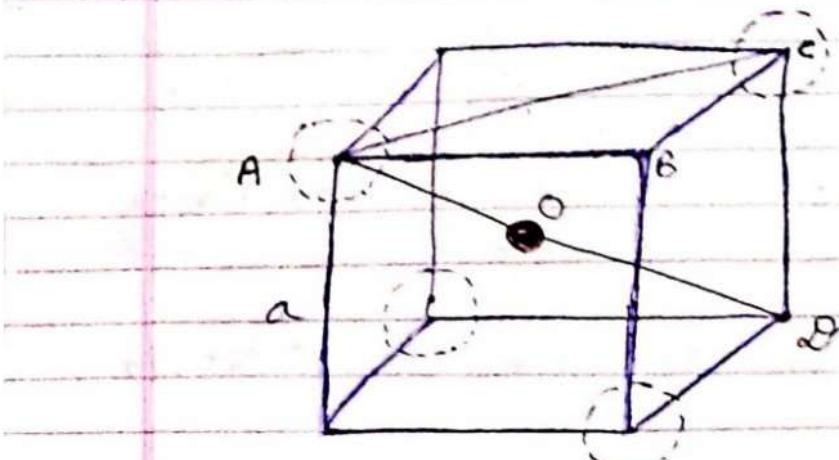
$$\frac{r_-}{r_+}$$

Q) Radius ratio for tetrahedral site :-

A tetrahedral site is formed by placing the anions at the alternate corners of a cube.

$$C.N = 4$$

Teacher's Signature \_\_\_\_\_



Cation and anions are touching to each other.

Surrounding atoms  $\rightarrow$  anion  
Central atom O  $\rightarrow$  cation

$$AC = 2r_-$$

$$AD = \sqrt{AO^2}$$

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

$$AC = \sqrt{2}a \quad \text{from face diagonal}$$

$$2r_- = \sqrt{2}a \quad \text{--- ①}$$

$$AD = \sqrt{AC^2 + CD^2} \quad \text{from body diagonal}$$

$$= \sqrt{2a^2 + a^2}$$

$$2(r_+ + r_-) = \sqrt{3}a$$

$$r_+ + r_- = \frac{\sqrt{3}a}{2} \quad \text{--- ②}$$

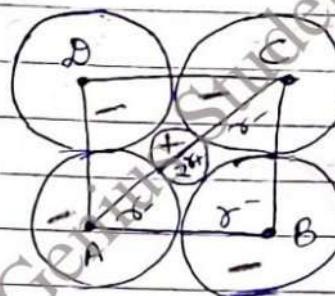
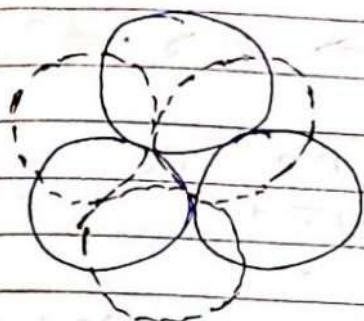
$$\text{from ② } r_- = \frac{r_+}{\sqrt{2}}$$

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

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

$$\frac{r_+}{r_-} = 0.225$$

③ Radius ratio for octahedral site :-



$$C.N = 6$$

Cross section of octahedral site

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

$$AB = a = 2r_-$$

$$2(r_- + r_+) = \sqrt{2}a$$

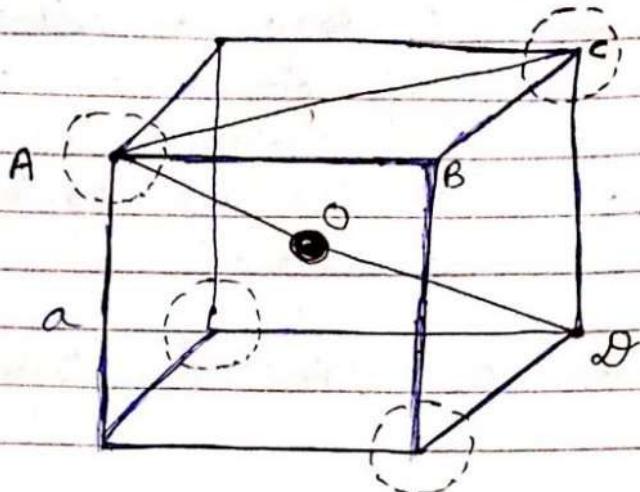
$$r_- = a/\sqrt{2}$$

$$r_+ + r_- = a/\sqrt{2}$$

$$r_+ = \frac{a - a}{\sqrt{2}} = \frac{2a - \sqrt{2}a}{2\sqrt{2}}$$

$$\frac{r_+}{r_-} = \frac{2a - \sqrt{2}a}{2\sqrt{2}} \times \frac{a}{a} = \sqrt{2} - 1 = 0.414$$

④ Radius ratio for cubic site :-



Cation and anions are touching to each other.

Surrounding atoms  $\rightarrow$  anion  
Centre atom O  $\rightarrow$  cation

$$AC = 2r -$$

$$AD = 2AO$$

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

$$AC = \sqrt{2}a \quad \text{from face diagonal}$$

$$2r_- = \sqrt{2}a \quad \text{--- (1)}$$

$$AD = \sqrt{AC^2 + CD^2} \quad \text{from body diagonal}$$

$$= \sqrt{2a^2 + a^2}$$

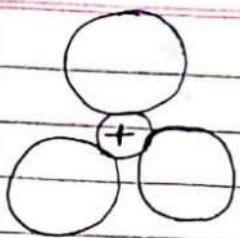
$$2(r_+ + r_-) = \sqrt{3}a$$

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

$$\text{from (1)} \quad r_- = \frac{a}{\sqrt{2}}$$

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

②

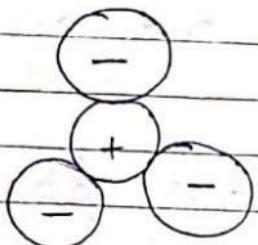


$$\frac{r^+}{r^-} = \text{Ideal}$$

stable

limiting cond?

③



$$\frac{r^+}{r^-} > \text{Ideal}$$

Highly stable

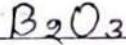
$$C.N = 3$$

$$0.155 - 0.225$$

Example

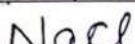
$$C.N = 4$$

$$0.225 - 0.414$$



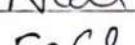
$$C.N = 6$$

$$0.414 - 0.732$$



$$C.N = 8$$

$$0.732 - 1$$

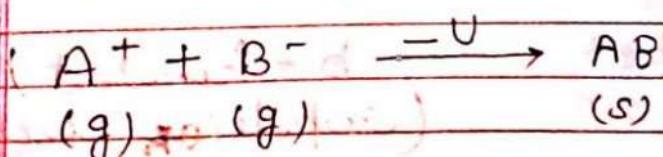


limiting radius ratio



## Lattice Energy of an ionic crystal

The L.E (U) of an ionic crystal is defined as the amount of energy released when cation and anion in their gaseous stage are brought from infinity to their respective lattice sites in a crystal to form 1 mole of the ionic crystal.



U = Lattice Energy

Teacher's Signature .....

## Calculation of Lattice Energy

### ① Theoretical Method

Lattice energy can be calculated by the help of Born and Lande Eqn.

Attractive Interaction b/w oppositely charged ions :-

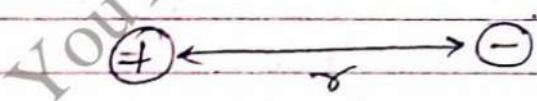
$$\text{P.E (attr)} = \frac{z_1 z_2 (e) (-e)}{r}$$

$$= -\frac{z_1 z_2 e^2}{r}$$

$z_1, z_2$  = are the charges

$e$  = electronic charge

$r$  = distance b/w ions



Repulsive interaction due to interpenetration of electron charge cloud :-

$$\text{P.E} = \frac{b e^2}{r^n} \quad b = \text{constant (repulsion coefficient)}$$

$n = \text{born exponent}$

Teacher's Signature

Value of  $n$  is with  $\uparrow$  in e<sup>-</sup> charge density

He config.	$n$	
Ne	5	Li <sup>+</sup> , Be <sup>+2</sup>
"	7	Na <sup>+</sup> , Mg <sup>+2</sup> , O <sup>-2</sup> , F <sup>-</sup>
Ar	9	K <sup>+</sup> , Ca <sup>+2</sup> , S <sup>-2</sup> , Cl <sup>-</sup>
Kr	10	Rb <sup>+</sup> , Br <sup>-</sup>
Xe	12	Cs <sup>+</sup> , I <sup>-</sup>

For a ion pair value of  $n$  is taken avg. e.g.  $\rightarrow$  LiCl

$$n = \frac{5+9}{2} = 7$$

Consider inter ionic forces due to all neighbouring ions.

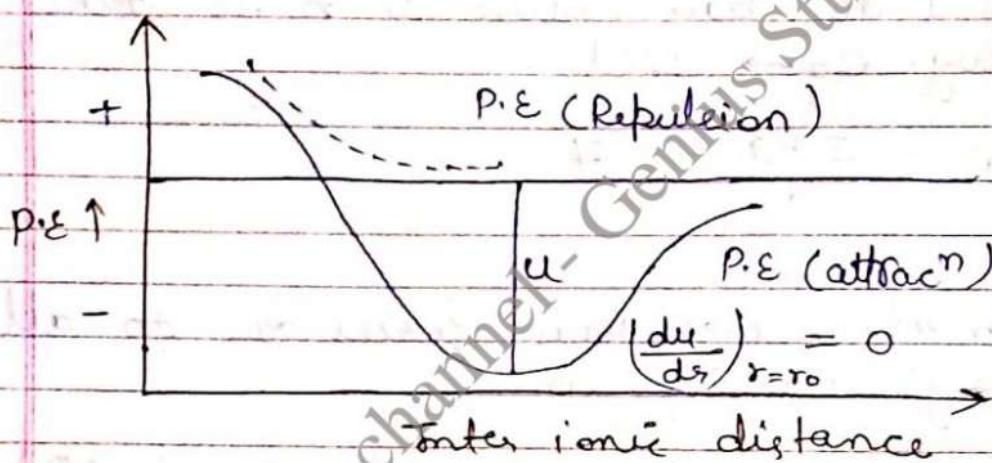
$$\begin{aligned} P.E. (\text{Net}) &= P.E. (\text{attr}^n) + P.E. (\text{rep}^n) \\ &= -\frac{z_1 z_2 e^2}{r} + \frac{be^2}{r^n} \\ &= -\frac{Z^2 e^2}{r} A + \frac{B}{r^n} \quad \leftarrow ① \end{aligned}$$

where  $A$  = mendeley's constant  
 $B = be^2 \times \text{no. of neighbouring ion}$

$z_1 = z_2 = \text{highest common factor}$

$$\text{Eq} \rightarrow \text{NaCl}, \text{Cell}_2 = 1 \\ \text{MgO}, \text{TiO}_2 = 2$$

An ion in ionic crystal will be stable in ~~Eq<sup>m</sup>~~ pos<sup>m</sup> when attractive & repulsive forces are equally balanced the P.E of the ion will be min<sup>m</sup> and differentiation of P.E w.r.t  $r$  at  $r=r_0$  will be 0.



$$\frac{d}{dr} \left\{ -\frac{z^2 e^2 A}{r} + \frac{B}{r^n} \right\} = 0$$

$$\frac{z^2 e^2 A}{r^2} - \frac{nB}{r^{n+1}} = 0$$

$$\frac{z^2 e^2 A}{r_0^2} = \frac{nB}{r_0^{n+1}}$$

$$B = \frac{z^2 e^2 A}{r_0^{n+1}} r_0^{n-1}$$

Put value of B in Eq. ①

$$P.E(\text{net}) = -\frac{z^2 e^2 A}{r_0} + \frac{z^2 e^2 A \gamma_0^{n-1}}{n \gamma_0^n}$$

$$P.E(\text{net}) = -\frac{z^2 e^2 A}{r_0} + \frac{z^2 e^2 A}{n r_0}$$

Lattice Energy =  $N_A \times U$   
( $U_0$ )

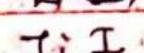
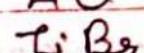
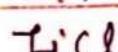
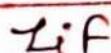
$$\star \left\{ U_0 = \frac{N_A z^2 e^2 A}{r_0} \left( \frac{1}{n} - 1 \right) \right. \begin{array}{l} n \geq 1 \\ \text{BORN} \\ \text{LA NDE Eq^n} \end{array}$$

Factors affecting Lattice Energy :-

① Ionic charges  $U_0 \propto z^2$   
 $\text{NaCl} < \text{MgO}$

② Interionic distance  $U_0 \propto \frac{1}{r_0}$

$$U_0 \propto \frac{1}{r_+ + r_-}$$



Size of Anion ( $r_-$ ) ↑

$$U_0 \downarrow$$

Teacher's Signature

LiF

NaF

KF

RbF

CsF

Size of cation ( $r^+$ ) ↑ $U_0 \downarrow$ 

### ③ Crystal str. (Madelung's constant)

$$U_0 \propto A$$

for NaCl  $A = 1.74756$

$\text{CaCl}_2$   $A = 1.76267$

$\text{ZnS}$   $A = 1.63806$

### ④ Born Exponent

$$n \uparrow \gamma_n \downarrow (\gamma_n - 1) \uparrow U \uparrow$$

$$U_0 \propto \left( \frac{1}{n} - 1 \right)$$

### ② Experimental Method

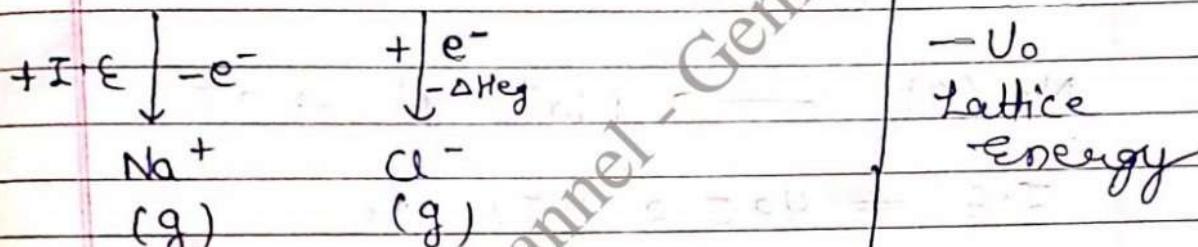
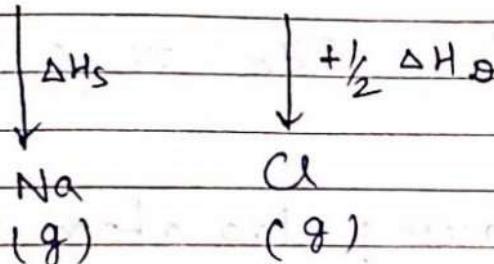
Experimentally  $L.E$  is calculated with the help of Born Haber cycle.

Born Haber cycle is a thermodynamic cycle which correlates heat of "form" of a ionic comp'd, "sublim"

2020

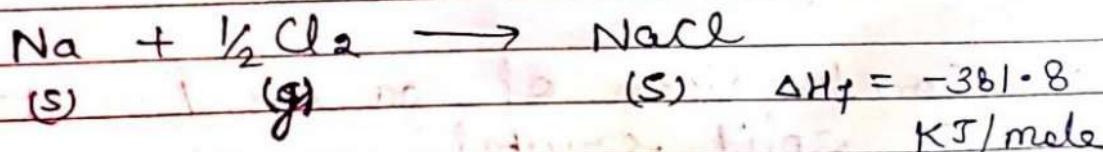
237

enthalpy, dissociation energy, ionization energy, Electron gain enthalpy, lattice energy.

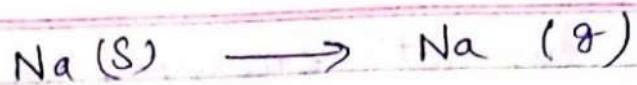


$$\Delta H_f = \Delta H_S + \frac{1}{2} \Delta H_d + J \cdot E + \Delta H_{eg} + U_0$$

(i) Direct form<sup>n</sup> of NaCl : →  
$$(s)$$

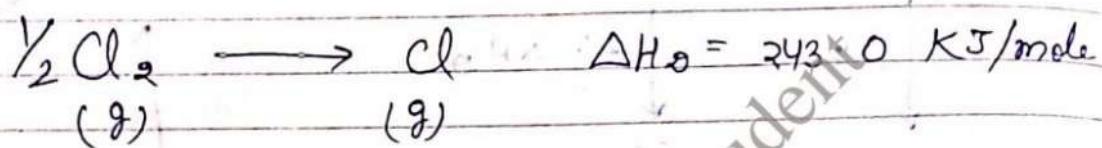


(ii) Conversion of metallic sodium into gaseous sodium atom :-

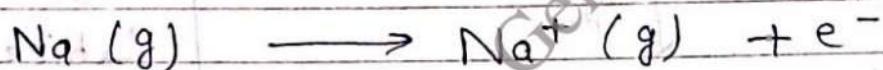


$$\Delta H_s = 108.5 \text{ kJ/mole}$$

(iii) Conversion of chlorine molecule into chlorine atom

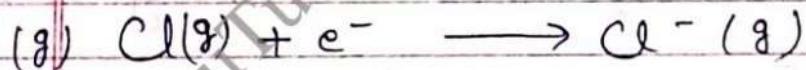


(iv) Conversion of gaseous Na atom into sodium ion



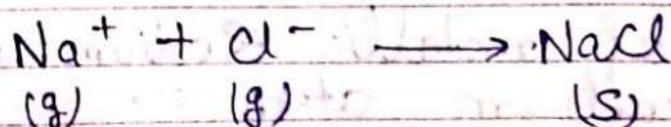
$$I.E = 495.9 \text{ kJ/mole}$$

(v) Conversion of gaseous Cl atom into Cl<sup>-</sup> ion



$$\Delta H_{eq} = -348.3 \text{ kJ/mole}$$

(vi) Combination of gaseous ions to form a solid crystal

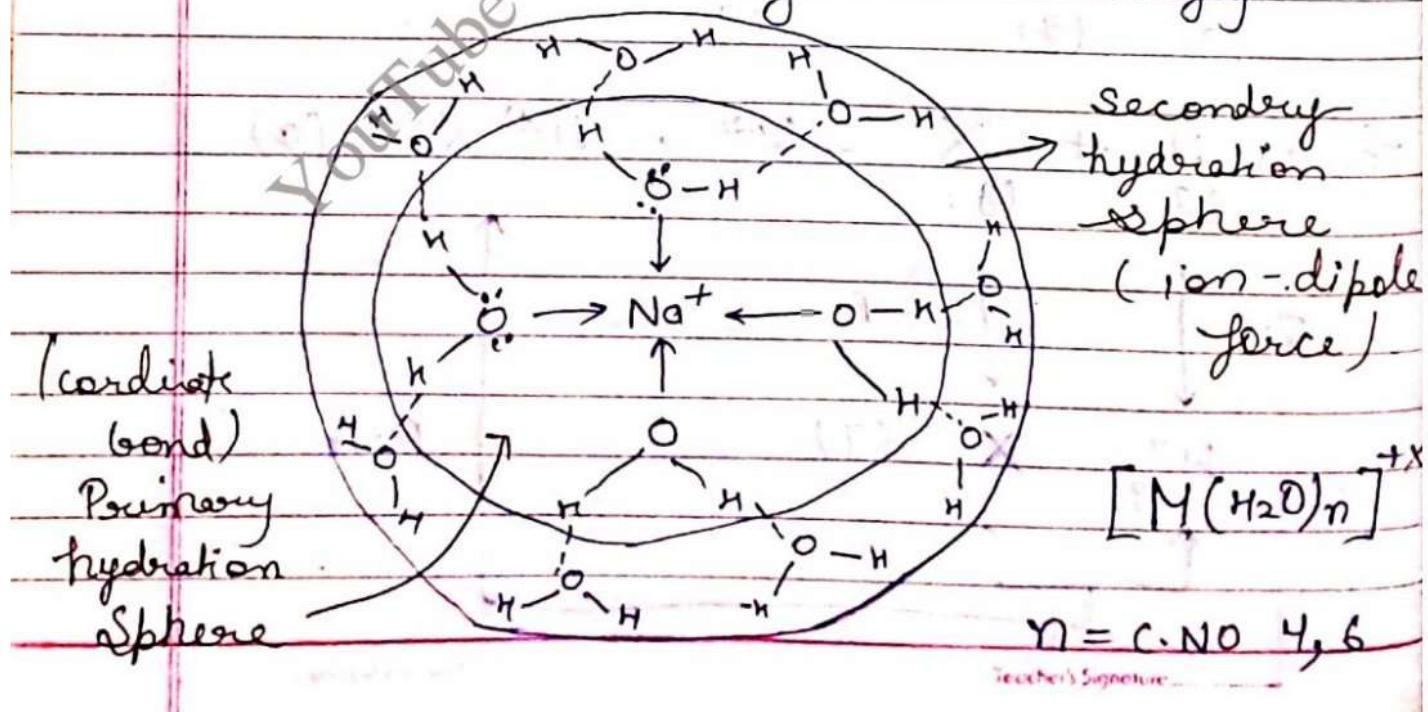


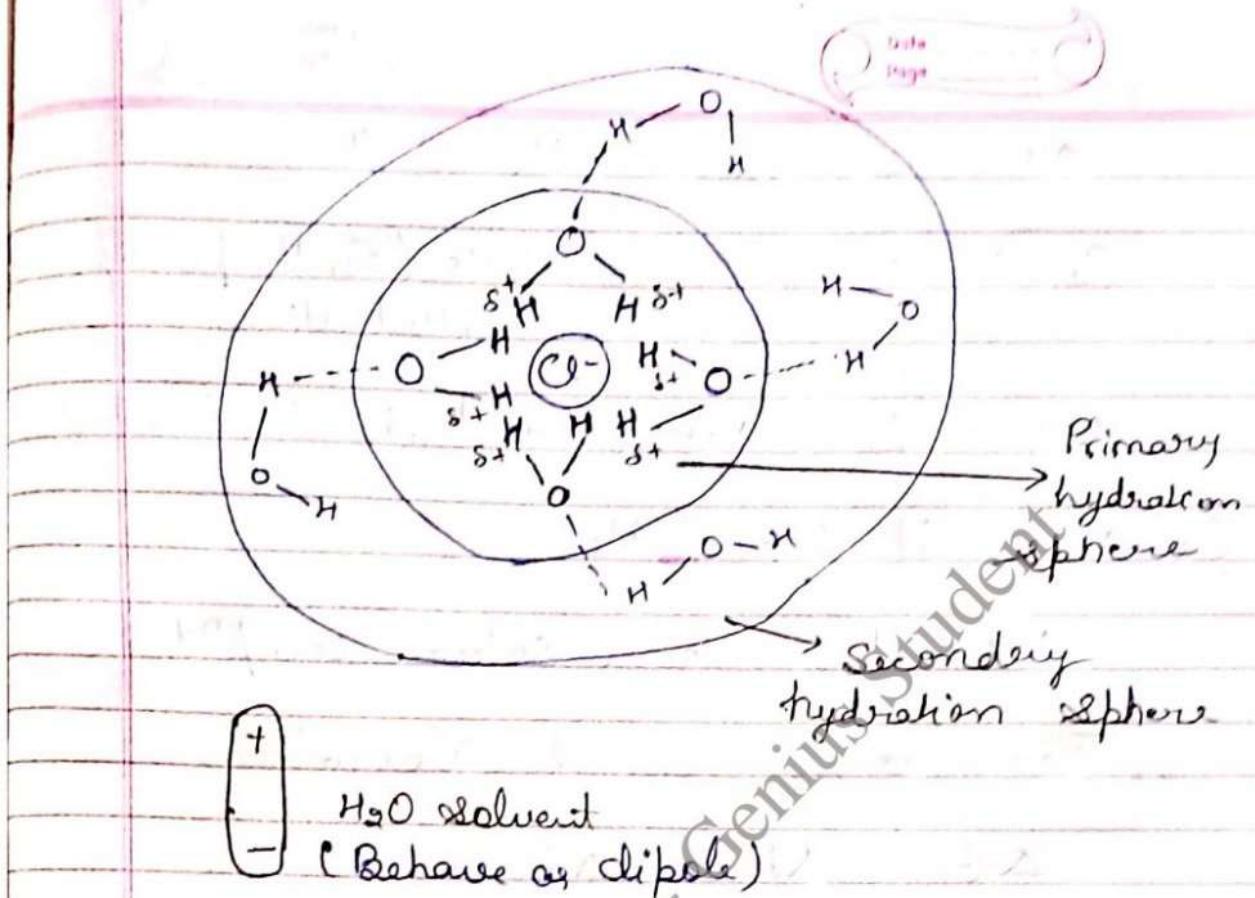
$$U_o = -758.7 \text{ kJ/mole}$$

## 2015 Solubility of Ionic Solids

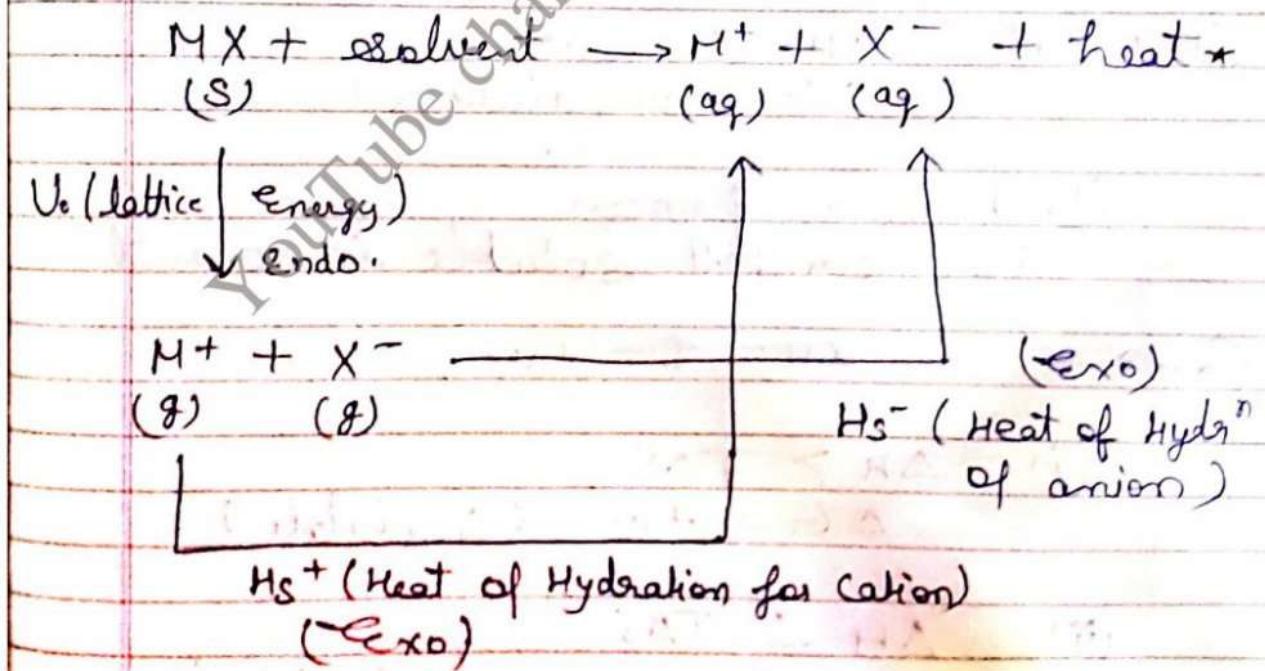
Like dissolves like i.e. ionic comp<sup>n</sup>d are soluble in polar solvent like as H<sub>2</sub>O, ROH, RCOOH, NH<sub>3</sub>, HF etc. while non-polar comp<sup>n</sup>d (covalent compounds) are soluble in non-polar solvents like as Benzene, CCl<sub>4</sub>, CS<sub>2</sub> etc.

When ionic comp<sup>n</sup>d is dissolved in polar solvent then its dissociation take place into ions. These ions are surrounded by solvent molecules. This process is known as solvation or hydration and amt of energy released during this process is known as solvation or hydration energy.





### Born Haber cycle for solubility



$\text{Hs}^+$  (Heat of Hydration for cation)  
(Exo)

$$* \text{Heat of dissolution } (\Delta H) = ?$$

Teacher's Signature

Scanned with CamScanner

Scanned with CamScanner

Scanned with CamScanner

## ~~2015~~ Factors affecting Solubility :-

### ① Dielectric constant

Dielectric constant is property or capacity of a solvent molecule by which electrostatic force of attraction decrease between ions.

$$H_s = \frac{z^2 e^2}{2\gamma} \left( 1 - \frac{1}{\epsilon} \right)$$

$\epsilon \uparrow$ ,  $1/\epsilon \downarrow$ ,  $\left( 1 - \frac{1}{\epsilon} \right) \uparrow$ ,  $H_s \uparrow$ , solubility  $\uparrow$

$\epsilon$  for  $H_2O = 80$  (Maximum)

### ② Ionic sizes

$$H_s = H_+ + H_-$$



$$H_s = \left. \frac{1}{r_+} + \frac{1}{r_-} \right\}$$

$$U_0 = \frac{1}{r_+ + r_-}$$



(i) if anion is larger than cation  
 $r_- > r_+$

$$\gamma_{r-} = \text{negligible}$$

$$H_s \propto \frac{1}{\gamma^+}$$

$$\gamma^+ + \gamma^- \approx \gamma^-$$

$$U_o \propto \frac{1}{\gamma^-}$$

$$\begin{aligned} \text{Solubility} &\propto H_s \\ &\propto \gamma_o \end{aligned}$$

Eg NaF NaCl NaBr NaI

Size of anion  $\uparrow$ ,  $U_o \downarrow$ , solubility  $\uparrow$

Eg BaSO<sub>4</sub> MgSO<sub>4</sub> CaSO<sub>4</sub> SrSO<sub>4</sub> BaSO<sub>4</sub>

Size of cation  $\uparrow$ ,  $H_s \downarrow$ , Solubility  $\downarrow$

Ques	$Li^+$	$Na^+$	$F^-$	$LiF, NaF$
$\gamma$	0.6	0.95	1.36	

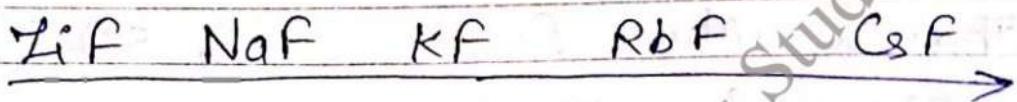
Solubility of which is greater?

Solve  $U_o = \frac{k}{1.95} \approx 0.51k$

Ans LiF

$$H_s = \left( \frac{1}{0.96} + \frac{1}{1.36} \right) K \approx 2.40 K$$

When cation and anion have comparable size then on decreasing size of cation  $L.E$  decreases more rapidly than hydration Enthalpy that's why solubility increases.



Size of cation  $\uparrow$ ,  $L.E$  and  $H.E \downarrow$ ,  
But  $L.E \downarrow$  more rapidly, Solubility  $\uparrow$

for  $\text{NaF}$     $U_s = \frac{K}{2.31} \approx 0.43 K$

$$H_s = \frac{1}{0.96} + \frac{1}{1.36} = 1.79 K$$

$$\begin{aligned} H_s &= 74.1 \\ U_s &= 84 \% \end{aligned} \quad \left. \begin{array}{l} \downarrow \\ \text{So take effect of } U_s \end{array} \right.$$

Hence overall solubility of  $\text{NaF}$  is greater than  $\text{LiF}$   
as  $U_s \downarrow$  Solubility  $\uparrow$ .

### ③ Ionic charges

On increasing ionic charges both lattice energy and hydration energy increases. But lattice energy increases more than hydration energy. Becoz solvent molecule have partial charges ~~that~~ and solubility increases.

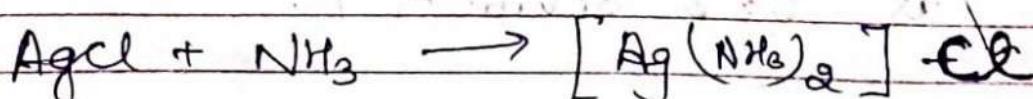
That's why  $\text{PO}_4^{3-}$ ,  $\text{CO}_3^{2-}$ ,  $\text{SO}_4^{2-}$  salt are less soluble.

### ④ Polarisation

On increasing polarising covalent character increases and solubility decreases.

$\text{Ag}^+$ ,  $\text{Cu}^+$ ,  $\text{Pb}^{2+}$  have pseudo inert configuration that's why salts of these ions are less soluble in water.

Eg  $\rightarrow \text{AgCl}$ ,  $\text{AgBr}$  and  $\text{AgI}$  are less soluble in water but more soluble in ammonia.



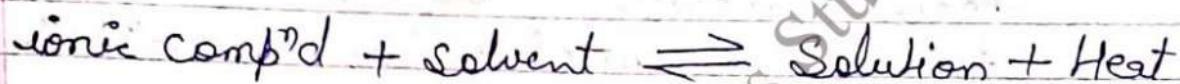
Q Date \_\_\_\_\_  
Page \_\_\_\_\_

⑤ Presence of other ions

In presence of common ion effect solubility decreases.

Eg → In presence of HCl solubility of NaCl decreases.

⑥ Effect of temp<sup>r</sup>



(i)  $\Delta H = +ve$  (Endothermic)

T ↑ solubility ↑

Eg → NH<sub>4</sub>Cl, KCl, AgNO<sub>3</sub>, NaNO<sub>3</sub>, KI

(ii)  $\Delta H = -ve$  (Exothermic)

T ↑ solubility ↓

Eg → NaOH, Li<sub>2</sub>SO<sub>4</sub>, (CH<sub>3</sub>COO)<sub>2</sub>Ca

for Gobba's salt ( $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ )

Solubility increases upto ~~32.4 °C~~ 32.4 °C  
after then started to decrease.

# Metallic Bond

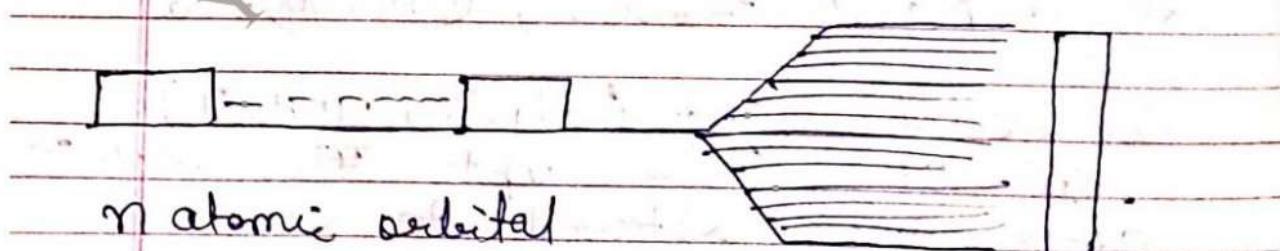
The bond present b/w metal atom in a metallic crystal is known as metallic bond.

## Band theory

When atoms come close to each other, their atomic orbitals overlap to form molecular orbital.

In a metallic crystal almost  $10^{23}$  atom are present which form  $10^{23}$  molecular orbital. They are so closely spaced looks like a band. Hence this theory is known as Band theory.

These molecular orbitals are delocalised all over crystal.



n atomic orbital

Band of an energy level

Teacher's Signature \_\_\_\_\_

Bands are of 2 types :-

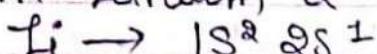
### ① Valence Band

The outermost filled energy band is known as valence band.

### ② Conduction Band

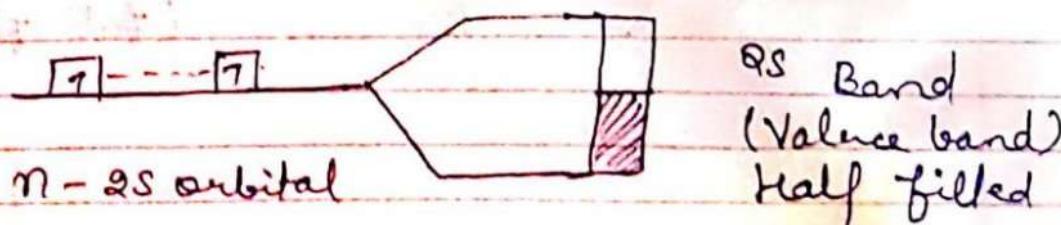
Next to valence band which is empty and in which  $e^-$  can move is known as conduction band.

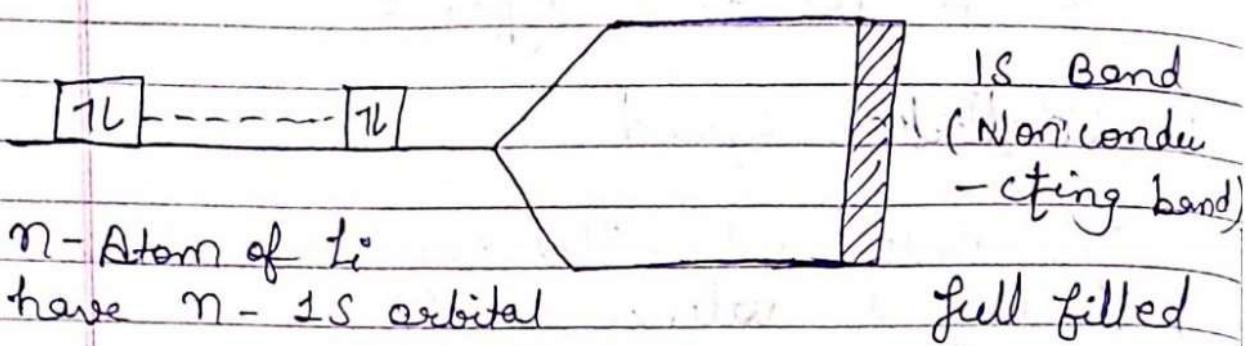
In lithium 2 types of bands are present.



(i) 1S Band  $\rightarrow$  These are completely filled and have no contributn in conductivity so known as non conducting band.

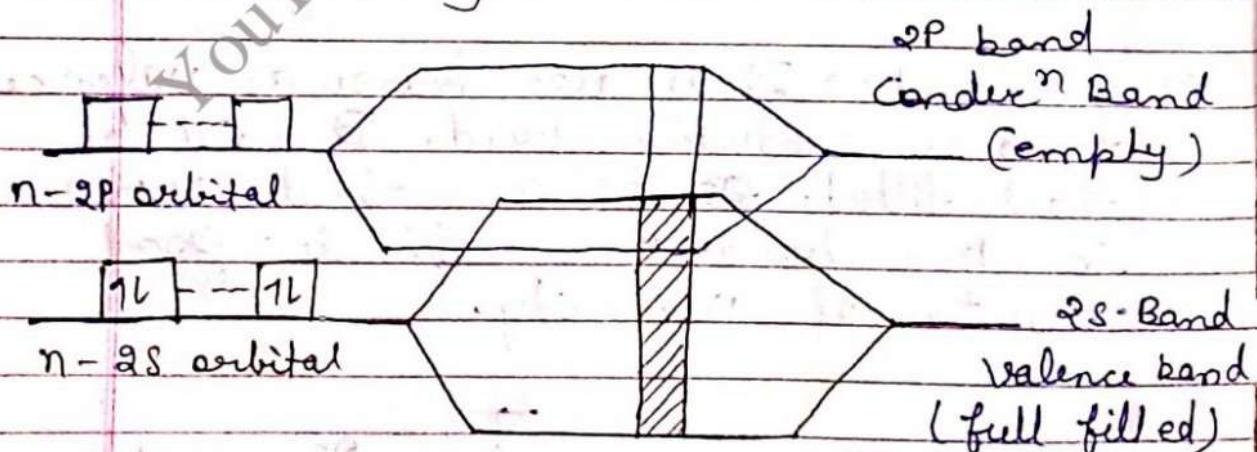
(ii) 2S Band  $\rightarrow$  It is also known as valence band or conduction band. It will be half filled.  $e^-$  can freely move in this band. Hence Li is good conductor of electricity.





~~In alkali metals outermost S orbital are completely filled and their energy band must be completely filled. And they should be insulators.~~

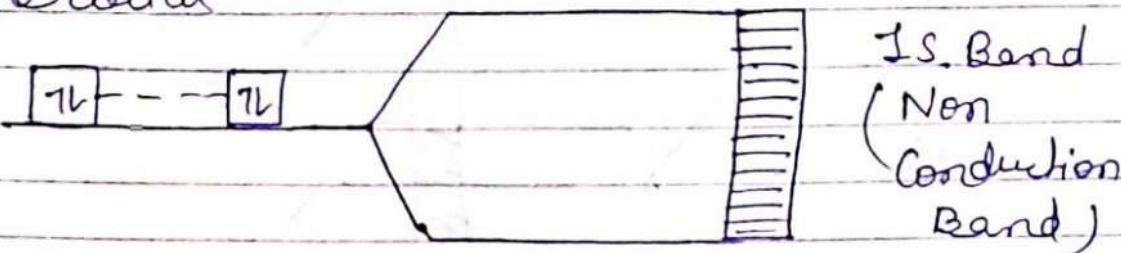
But Band formed ns and np orbital overlapped to each other due to less energy difference and some electrons move  $\downarrow$  valence band to conduction band {from} and show conductivity.



Eg of Beryllium

n atom of Be

have n 1s orbital



## Insulator

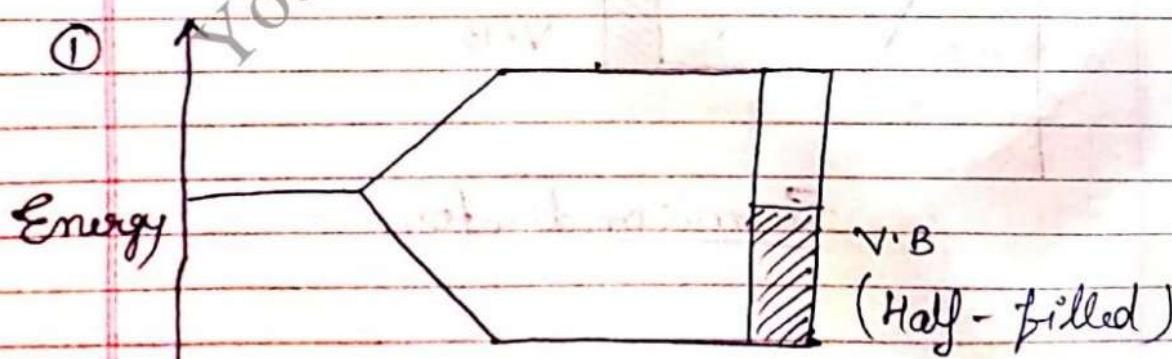
In these energy gap b/w valence band and conduction band is so large that  $e^-$ 's cannot be excited valence band to conduction band.

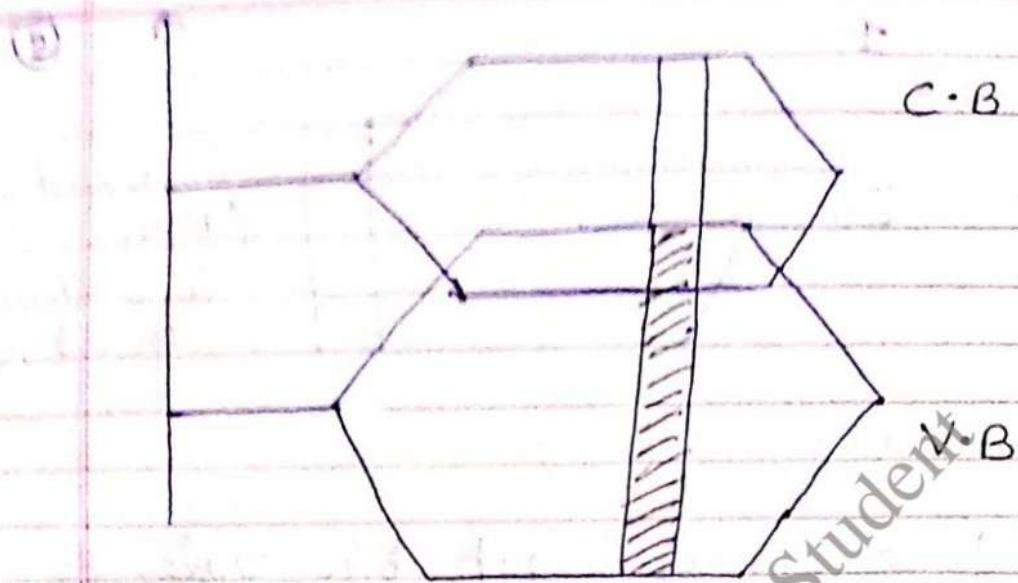
glass, wood, diamond

## Semi-Conductor

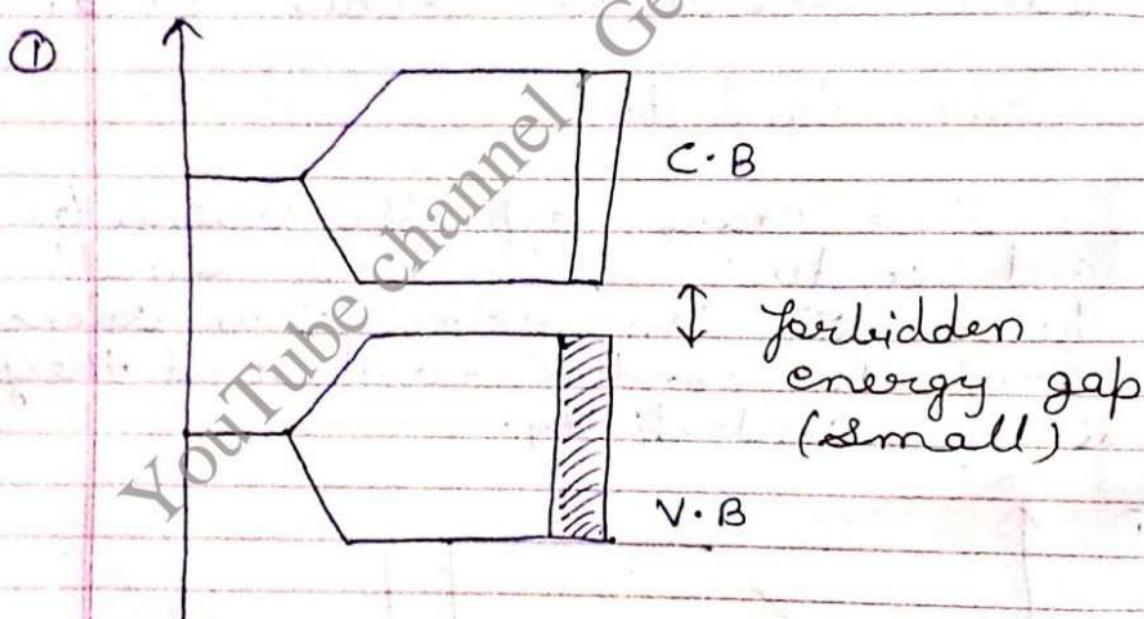
In these energy gap b/w valence band and conduction band is small hence  $e^-$  can be excited from valence band to conduction band and they show conductivity. (Si, Ge). Eg

①



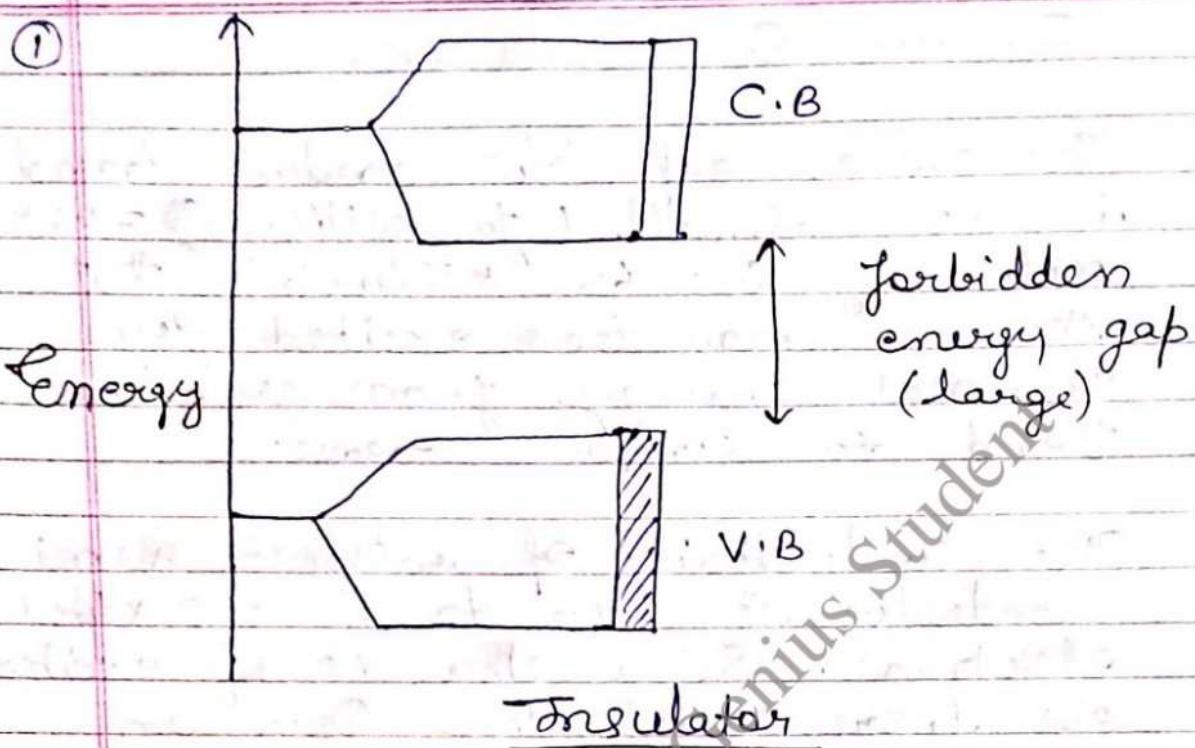


Metals  $\rightarrow$  Conductor

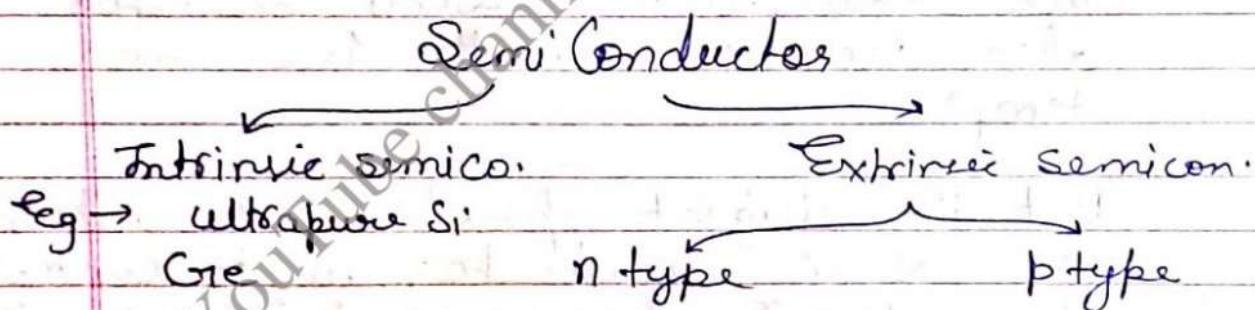


Semiconductor

Teacher's Signature



Classification of semi conductor :-



gp 15 element  
are mixed as  
impurities.

gp 13 element  
are mixed as  
impurities.

## Intrinsic Semiconductors

The energy gap b/w conduction band is also small (for silicon  $\approx 106 \text{ KJ/mole}$ , for Ge  $68 \text{ KJ/mole}$ ) that the  $e^-$  may be excited by thermal energy from valence band to conduction band.

The conductivity of intrinsic semiconductors is due to these excited electrons. Since the no of excited  $e^-$ s increases with the increase in temp<sup>r</sup>.

The conductivity of semiconductors also increases with increase in temp<sup>r</sup>.

But the biggest problem of intrinsic semiconductors is to control their temp<sup>r</sup> bcoz at higher temp<sup>r</sup> more and more  $e^-$  are excited to conduction band from the valence band as a result no of  $e^-$ s taking part in bonding decreases and the crystal break down.

Teacher's Signature.....

## Extrinsic Semi Conductor

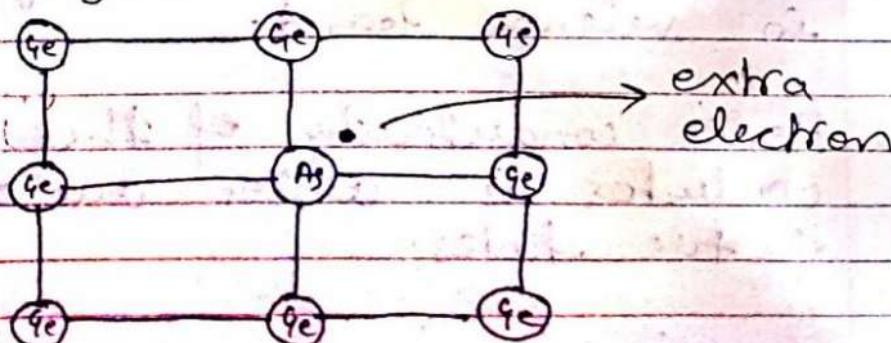
The process of mixing of impurity in intrinsic semi conductor is known as Doping and formed semi conductor are known as Extrinsic semi conductor.

These are of 2 types

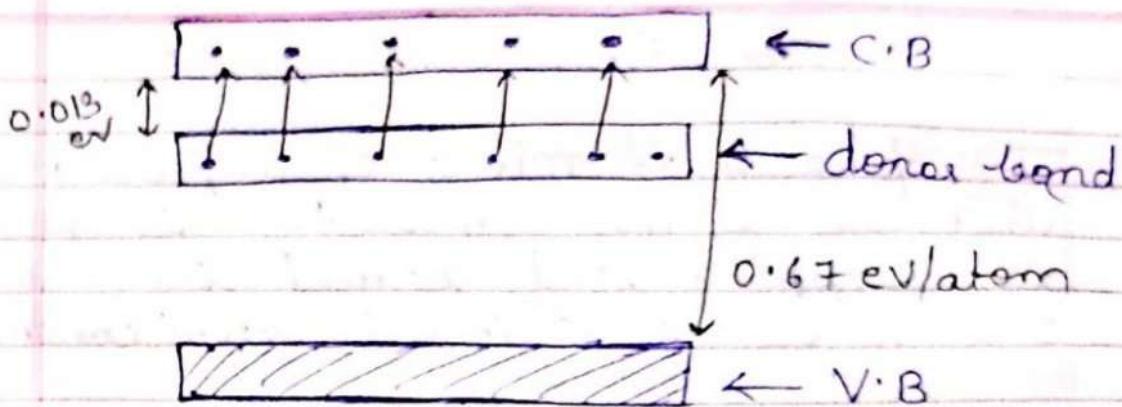
### ① n type Semiconductor

When Si, Ge is doped with impurities of group 15 elements (N, P, As, Sb, Bi) then some Si or Ge atom replaced by these impurities out of 5 electrons, 4 e<sup>-</sup> take part in bonding while 1 extra electron remain. These extra e<sup>-</sup> forms donor band just below conduction band. These e<sup>-</sup> can be excited from donor band to conduction band.

This type of impurity are also called as donor impurity or e<sup>-</sup> rich impurity.



Teacher's Signature

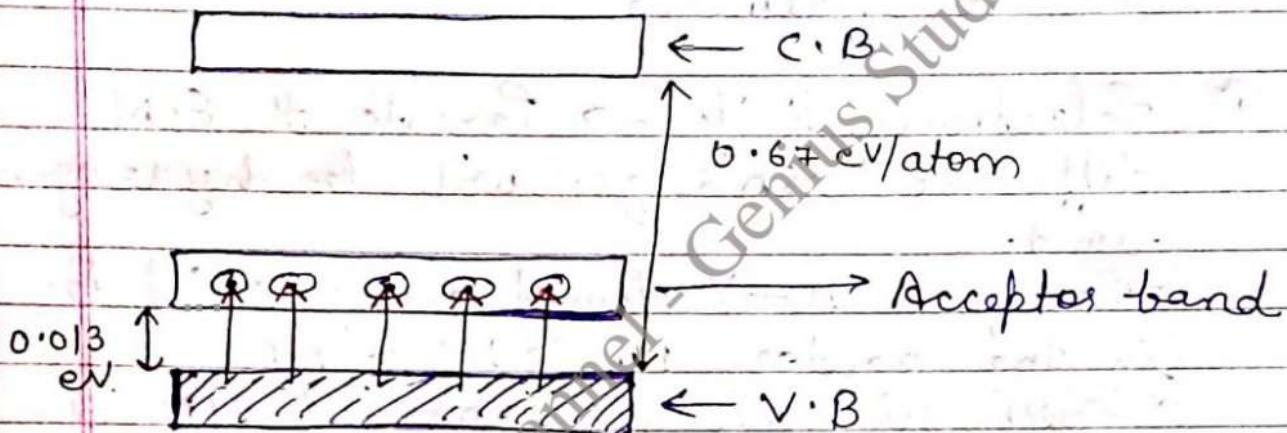
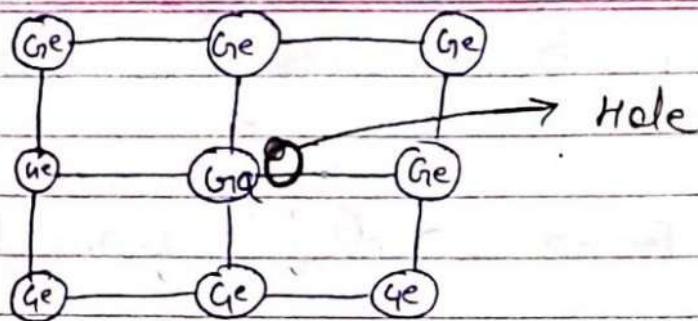


## ② p type semi conductor

when Si, Ge is doped with impurities of group 13 elements (Al, Ga, In, Tl) then P-type semi-conductors is formed. Impurities have only 3 valence e<sup>-</sup>s due to which a hole is generated as a result, a new energy band which is known as acceptor band is formed just above valence band.

At room temp<sup>o</sup> e<sup>-</sup>s are transferred from valence band to acceptor band. And hole is generated in valence band.

Hence conductivity of these types semi-conductors is arises due to "migration" of free holes.



- Effect of temp<sup>r</sup> on Conductivity :-

On increasing temp<sup>r</sup> conductivity of metals decreases becoz due to thermal energy scattering of atoms decreases vibration.

due to which scattering of valence shell e<sup>-</sup> increases and resistance of metal decreases and conductivity increases.

while for semi conductor conductivity increases on increasing temp<sup>r</sup>.