Ionic Bond, Latice energy, Characteristic of Ionic Compounds

- "The strong electrostatic attraction between two oppositely charged ions which are formed due to transfer of electrons from one atom to another is called Ionic Bond (or) Electrovalent Bond".
- 2. Mostly Ionic Bond is formed between a metal and a non metal.
- 3. Formation of Ionic bond is a redox process because metal atom undergoes oxidation and non-metal atom undergoes reduction.

In MgO Electrovalency of Mg = 2, O=2

In Na₂O electrovalency of Na = 1, O = 2

*The maximum electrovalency in the formation of Ionic Bond is 3.

- 4. For Ionic bond formation the electro negativity difference between two bonded atoms should be greater than 1.7.
- 5. Most ionic bond is formed between IA and VIIA group elements.

6.	Metal (M)		(M) Non-metal(X)	Formula
	i.	IA	VIIA	MX
	ii.	IA	VIA	M2X
	iii.	ПА	VIIA	MX2
	iv.	IIA	VIA	MX

7. Conditions favourable for the formation of an ionic bond are

- a. Cation favourable Conditions
- i. Large atomic size
- ii. Low I.P

- iii. Low Charge on cation
- iv. Cation with inert gas configuration are more stable than cation with pseudo inert gas configuration. *Pseudo inert gas configuration is also called as nickel group configuration.
- b. Anion Favourable Conditions

i. Small size of atom

ii. High E.N (or) E.A

iii. Low charge on anion

- 8. During the formation of an ionic bond when two oppositely charged ions of unequal size closely approach each other, the ion smaller in size attracts outermost electrons of the other ion and repels its nuclear charge. The net result is distortion or deformation or polarisation of the larger ion.
- 9. The distortion is generally done by the cation as its size is smaller than anion. The electron cloud of anion no longer remains symmetrical but is elongated towards the cation.
- 10. The ability of a cation to polarise the nearby anion is called its polarising power or polarisation ability.
- 11. The tendency of an anion to get distorted or deformed or polarised by the cation is said to be polarisability. As a result of polarisation, sharing of electrons takes place between two ions to some extent and the bond shows some covalent character.
- 12. The magnitude of the polarisation or the increased covalent character is favoured by a number of factors. These factors are known as Fajan's rules and are useful in predicting the nature of the bond formed between two atoms.

FAJAN'S Rules

i. Increase in size of the cation increases the ionic nature of the bond.

E.g. As size of $Li^+ < Na^+ < K^+ < Rb^+ < Cs^+$ the ionic character of LiCl < NaCl < KCl < RbCl < CsCl

The order of increasing covalent character is:

 $NaCl < MgCl_2 < AlCl_3 < SiCl_4$, because the charge on the cation increases

ii. Increase in size of the anion favours the covalent bond.

As size of $F^- < Cl^- < Br^- < I^-$, the ionic character of $CaF_2 < CaCl_2 < CaBr_2 < CaI_2$

Among the halides of calcium, CaF_2 is more ionic and CaI_2 is more covalent. Among the halides of silver, AgF is more ionic and AgI is more covalent.

iii. Highly charged cation and anion form covalent bonds.

NaCl is more ionic compared to the ionic nature of AlCl₃. In NaCl both cation and anion have low charges while in AlCl₃ the cation Al³⁺, is of a higher charge than Na⁺ while the anion is the same in both compounds. According to the Fajan's rule, AlCl₃ is more covalent in nature.

iv. Cations with inert gas configuration form ionic compounds while cations with pseudo inert gas configuration favour the formation of covalent compounds.

E.g.-NaCl is ionic because Na⁺ ion in NaCl has inert gas configuration. CuCl is more covalent because Cu⁺ ion has pseudo inert gas configuration.

v. Most favourable conditions for ionic bond are: large cation, small anion and small magnitudes of charge on both the ions.

Crystal Structures of Ionic Compounds

- i. The regular arrangement of ions in the crystal of an ionic solid is called 'Crystal lattice'.
- ii. The smallest repeating part of the crystal lattice that represents entire crystal lattice in properties is known as the unit cell.
- iii. Unit cell of ionic compound contain oppositely charded ions called 'Unit particles'.

iv. The number of oppositely charged ions that surround a particular ion in an ionic crystal is known as the co-ordination number of that ion.

Example: Co-ordination number of Na^+ and Cl^- in NaCl is 6.

Co-ordiantion number of Cs^+ and Cl^- in CsCl is 8.

14. The shape of ionic crystal and Co-ordiantion number depends on cation to anion radius ratio (i.e. r_c/r_a value) called 'Limiting Radius Ratio'

Limiting radius	Coordination	Shape or
ratio	number	structure
< 0.155		Linear
0.155 - 0.225	3	Planar triangle
0.225 - 0.414	4	Tetrahedral
0.414 - 0.732	4	Square planar
0.414 - 0.732	6	Octahedral
0.732 - 0.999	8	Body centred

15. The r_c / r_a for NaCl is 0.52. Thus NaCl has F.C.C Lattice

www.sakshieducation.com

- 16. The r_c/r_a for CsCl is 0.93. Thus CsCl has b.c.c Lattice
- 17. Co-ordination number of cations and anions may (or) may not be same

Ex: In CaCl₂, Co-oridination number of Ca²⁺ is 8 but Cl⁻ is 4

*Chlorides, bromides and iodides of Na, K or Rb, Oxides and sulphides of IIA group elements (except Be), Silver halides (except AgI) have FCC lattice. CsCl, CsBr and CsI are in BCC lattice.

18. Lattice energy: The lattice energy of an ionic crystal is the amount of energy released when one mole of crystal is formed from the oppositely charged gaseous ions (or) the amount of energy needed to disperse one mole of ionic crystal into isolated constituent gaseous ions. This is denoted by "U".

E.g. -- Na⁺ (g) + Cl⁻(g) NaCl(s);
$$U = -775.0$$
kJ mol⁻¹

- 19. Lattice energies of ionic crystals cannot be measured directly, but experimental values are obtained fromthermodynamicdata using the Born-Haber cycle. The cycle is based on Hess's law of constant heat summation. Which states that the total energy change in a chemical reaction remains the same whether the reaction takes place in one step or in several steps?
- 20. The lattice energy is equal to the sum of the attractive and repulsive forces

$$U = -\frac{N_0AZ^+Z^-e^2}{r} + \frac{N_0B}{r^n}$$

attractive force force

Here N₀=Avogadro's number.

- A = Madelung constant which depends on the geometry of the crystal.
- Z^+ and Z^- are the charges on the positive and negative ions,
- 'e' is charge on the electron,

B is repulsive coefficient. B depends on the structure and it is approximately proportional to the number of nearest neighbours.

'r 'is the interionic distance and n is Born exponent constant(it is often taken as 9).

21. The equilibrium distance between ions is determined by the balance between

the attractive and repulsion terms. At equilibrium $B = \frac{AZ^+Z^-e^2r_0^{n-1}}{n}$ substituting

it in the expression of U,
$$U = \frac{N_0 A Z^+ Z^- e^2}{r_0} \left(1 - \frac{1}{n}\right)$$

This equation is called Born-Lande equation

22. Lattice energy is inversely proportional to the sum of the radii of cation and anion.

Lattice energy $\alpha \frac{1}{(r_c + r_a)}$

23. The heat energy released when one gram mole of NaCl(s) is formed by the combination of Na(s) and Cl2 (g) is known as the heat of formation of NaCl(s). It is represented by ΔH .

The lattice energy of NaCl(s) can be calculated by using the following formula

$$-\Delta H = +S + I + \frac{D}{2} - (E + U)$$

 ΔH . = heat of formation of NaCl

S = Sublimation energy of Na

- I = I.P. of Na
- $D = Dissociation energy of Cl_2$
- E = Electron affinity of Cl
- U = Lattice energy

$$Na_{(s)} + \frac{1}{2}Cl_{2(g)} \rightarrow NaCl_{(s)} \quad \Delta H = -\Delta H_{f}$$

$$\Delta H_{1} = S.E \qquad \Delta H_{3} = D/2 \qquad (Exo)$$

$$Na_{(g)} \qquad Cl_{(g)} \qquad \Delta H_{4} = -E.A \qquad (Exo)$$

$$AH_{2} = I.P \qquad \Delta H_{4} = -E.A \qquad (Exo)$$

$$Na_{(g)}^{+} + Cl_{(g)}^{-} \qquad (Exo)$$

According to Hess Law,

Endo

$$\begin{array}{c} Exo \\ +\\ (g) \end{array} + Cl_{(g)}^{-} \end{array} \\ According to Hess Law, \\ \Delta H = \Delta H_1 + \Delta H_2 + \Delta H_3 + \Delta H_4 + \Delta H_5 \Longrightarrow - \Delta H_f = S.E + I.P + \frac{D}{2} - E.A - U \end{array}$$

24. Lattice energy depends upon

i. Charge on ions: The higher the charge on ions, the greater will be the force of attraction between them and greater will be the lattice energy. The order of lattice energy for different solids is as follows

bi - bivalent solids > uni-bivalent solids > uni-univalent solids

E.g. -MgO> CaCl₂> NaCl

ii. Size of ions: The smaller the size of the ions, the lesser will be distance between them, the greater will be the force of attraction and so greater will be the lattice energy.

E.g.-The order of lattice energy for LiCl >NaCl >KCl>RbCl>CsCl

25. Higher the latice energy, greater is the stability of ionic solid.

26. Latice energy influence melting temparature, solubility etc.

Calculation of number of ions per Units cell

27. The number of ions per Units cell is calculated from the position occupied by ions in the unit cell i.e lattice points. In different cubic unit cells there are mainly four kinds of lattice points. They are:

Lattice point (position of ion)	No.of unit cells sharing the ion	contribution of the ion to one unit cell
Body center	1	1
Face center	2	1/2
Edge center	4	1/4
Corner	8	1/8

Structure of NaCl AND CsCl Crystals

In NaCl, Na⁺ ions present at body centre and at edge centres of unit cell. Thus Effective number of Na⁺ ions present per unit cell = 1+12x1/4=4

SU.

Similarly, Cl⁻ ions present at the corners and at face centere of unit cell.

Effective number of Cs⁺ ions present per unit cell = 8x1/8+6x1/2=4

There are four Na⁺ ions and four Cl⁻ ions per unit cell of sodium chloride. In other words, four ion pairs are present per unit cell. Similarly each unit cell of CsCl has one ion pair.

28. One unit cell of NaCl contains 4 formula units.

Mass of one unit cell of $NaCl = 4 \times 58.5 = 234 \text{ a.m.u}$

Mass of onemole unit cells of NaCl = 234 gm

- 29. 234 gm of NaCl= 2.4×10^{24} formula units= 6.023×10^{23} unit cells.
- 30. One unit cell of CsCl contains one formula unit.

One gram formula weight of CsCl contains 6×10^{23} unit cells.

Properties of Ionic Compounds

- i. Ionic compounds exist as crystalline solids.
- ii. They are generally soluble in polar solvents (having high value of dielectric constant). The solubility of ionic compounds decreases with increase in Lattice energy. More the lattice energy, lesser is the solubility.

E.g. Sulphates and carbonates of Ba and Sr are insoluble in water due to high lattice energy than the heat of hydration.

- iii. Ionic compounds are non conductors in solid state but good electrical conductors in molten state (or) in aqueous solutions due to free ions.
- iv. Ionic compounds react quickly in aqueous solutions.
- v. Ionic compounds do not exhibit space isomerism as ionic bond is non directional.
- vi. The melting and boiling points of ionic compounds are very high due to the strong electrostatic forces of attraction between the ions.

Example: Melting point of NaCl is 803⁰C.

*If the anion is common in ionic compounds, the more ionic compond with its cations having high atomic wight will have more melting point.

E.g: Melting point of is very high compared with.

Melting point of CsF is very high compared with LiF.

*If cation is common in the ionic compounds, compound with high lattice energy will have high melting point and the compound with low lattice energy will have low melting point.

Example: Melting point of NaF is more than that of NaI. Of ionic compounds decreases with increase in Lattice energy more the lattice energy, lesser is the

solubility, eg. Sulphates and carbonates of Ba and Sr are insoluble in water due to high lattice energy than the heat of hydration.

- iii. Ionic compounds are non conductors in solid state but good electrical conductors in molten state (or) in aqueous solutions due to free ions.
- iv. Ionic compounds react quickly in aqueous solutions.
- v. Ionic compounds do not exhibit space isomerism as ionic bond is non directional.
- vi. The melting and boiling points of ionic compounds are very high due to the strong electrostatic forces of attraction between the ions,

Example: Melting point of NaCl is 803⁰C.

MAR

*If the anion is common in ionic compounds, the more ionic compond with its cations having high atomic wight will have more melting point.

E.g: Melting point of is very high compared with.

Melting point of CsF is very high compared with LiF.

*If cation is common in the ionic compounds, compound with high lattice energy will have high melting point and the compound with low lattice energy will have low melting point.

Example: Melting point of NaF is more than that of NaI.