Note :

- **Valence electrons :** It refers to the outer shell electrons (of an atom) that take part in chemical combination in the formation of a molecule.
- The inner shell electrons are well protected and are generally not involved in the combination process.
- **Common or group valence of an element :** It generally refers to no of valence electrons or 8 minus the number of valence electrons.
- Atoms can combine either by transfer of valence electrons from one atom to another (gaining or losing) or by sharing of valence electrons in order to have an octet in their in their valence shells. This is known as octet rule.

IONIC OR ELECTROVALENT BONDING Section - 2

The chemical bond formed due to electrostatic attraction between cations and anions (which are formed by the complete transfer of electron(s) from one atom to the other atom) is called as Electrovalent or Ionic Bond. The Ionic valency or Electrovalence is referred to as the number of electrons that an atom can give up or gain. In other words it is equal to the number of unit charge(s) on the ion, eg. In NaCl, sodium is assigned a positive electrovalence of one, while chlorine a negative electrovalence of one.

The formation of a positive ion involves ionization, i.e., removal of electron(s) from the neutral atom and that of the negative ion involves the addition of electron(s) to the neutral atom.

$$M(g) \longrightarrow M^{+}(g) + e^{-} \; ; \quad \text{Ionization enthalpy}$$

$$X(g) + e^{-} \longrightarrow X^{-}(g) \; ; \quad \text{Electron gain enthalpy}$$

$$M^{+}(g) + X^{-}(g) \longrightarrow MX(s) \; ; \quad \text{Lattice energy}$$

Formation of Lattice :

The compounds which are formed by ionic bonds are mostly solids. These compounds crystallize in different crystal structures determined by factors such as size of the ions, their packing arrangements etc. In the crystalline state, these compounds consist of orderly three-dimensional arrangements of cations and anions (*which is called* lattice) held together by coulombic interaction energies. The energy released when such an arrangement is formed (due to electrostatic attraction) is known as Lattice Energy.

The lattice is a highly stable arrangement and hence all ionic compounds have high melting and boiling points. The higher is the lattice energy, the more stable is the ionic bond.

Factors affecting lattice energy :

Magnitude of charge : More is the magnitude of charge on cation or anion, the more is the lattice energy. For example, the lattice energy of $MgCl_2$ is higher than that of NaCl.

Size of ions **:** For higher lattice energy, the cations should be smaller and anion should be larger. The smaller is the cation, the more effective is the nucleus in pulling the neighbouring anions towards it. As a result, the lattice formed is highly stable or we can say that the lattice energy is high. Eg : Lattice energy of NaCl is greater than that of CsCl, as Na^{+} cation is smaller than Cs^{+} cation though the ionisation energy of Cs is much lower than that of Na.

Elaboration :

- There is a formation of negative ion from a halogen atom and a positive ion from an alkali metal atom due to gain and loss of an electron by the respective atoms.
- The negative and positive ions thus formed attain stable noble gas electronic configurations. The noble gases (with the exception of helium which has a duplet of electrons) have a particularly stable outer shell configuration of eight (octet) electrons, ns^2np^6.
- The negative and positive ions are stabilized by electrostatic attraction.

For example, the formation of NaCl from sodium and chlorine, according to the above scheme, can be explained as :

$$\begin{array}{lcl} Na & \longrightarrow & Na^+ + e^- \\ [Ne]\,3s^1 & & [Ne] \\ Cl + e^- & \longrightarrow & Cl^- \\ [Ne]\,3s^2\,3p^5 & \longrightarrow & [Ne]\,3s^2\,3p^6 \text{ or } [Ar] \\ Na^+ + Cl^- & & NaCl \text{ or } Na^+Cl^- \end{array}$$

Similarly the formation of CaF_2 may be shown as :

$$\begin{array}{lcl} Ca & \longrightarrow & Ca^{2+} + 2e^- \\ [Ar]\,4s^2 & & [Ar] \\ F + e^- & \longrightarrow & F^- \\ [He]\,2s^2\,2p^5 & & [He]\,2s^2\,2p^6 \text{ or } [Ne] \\ Ca^{2+} + 2F^- & \longrightarrow & CaF_2 \text{ or } Ca^{2+}(F^-)_2 \end{array}$$

Other examples of molecules involving ionic bonds are MgO, $AlCl_3$, KI, CaS, $MgBr_2$, etc.

Ionic Bonding formation depends on the following :

1. Ionisation Enthalpy ($\Delta_i H$) or ease of formation of positive ions.

2. Electron Gain Enthapy (Δ_{eg} H) / Eectron Affinity (A_e) or ease of formation of negative ions.

3. Lattice Enthalpy

Ionisation Enthalpy (Δ_i H) : It is the energy required to remove an electron from an isolated gaseous atom in its ground state.

Electron Gain Enthalpy (Δ_{eg} H) : It is the energy required to add an electron to a gas phase atom in its ground state to form a negative gaseous ion.

Note : The electron gain process may be exothermic or endothermic. The ionization, on the other hand, is always endothermic.

Electron affinity (A_e) : It is the energy released when an electron is added to a neutral gaseous atom in its ground state to form a negative ion. *Electron Affinity of an atom is defined only at absolute zero temperature.*

Lattice Energy : Energy released when gaseous positive and negative ions come together to form 1 mol of solid (crystalline) ionic compound.

Lattice Enthalpy : The Lattice Enthalpy of an ionic solid is defined as the energy required to completely separate one mole of a solid ionic compound into gaseous constituent ions. For example, the lattice enthalpy of NaCl is 788 kJ/mole (and Lattice energy = –788 kJ/mol). This means that 788 kJ of energy is required to separate one mole of solid NaCl into one mole of $Na^+(g)$ and one mole of Cl^- to an infinite distance.

Note : Condition for formation of a stable ionic compound is :
Total Ionisation enthalpy + Total Electron Gain Enthalpy – Total Lattice Enthalpy < 0

Simple Binary Ionic Compounds

Metal	Nonmetal	General Formula	Ions Present	Example
IA	VIIA	MX	(M^+, X^-)	LiBr
IIA	VIIA	MX_2	$(M^{2+}, 2X^-)$	$MgCl_2$
IIIA	VIIA	MX_3	$(M^{3+}, 3X^-)$	GaF_3
IA	VIA	M_2X	$(2M^+, X^{2-})$	Li_2O
IIA	VIA	MX	(M^{2+}, X^{2-})	CaO
IIIA	VIA	M_2X_3	$(2M^{3+}, 3X^{2-})$	Al_2O_3
IA	VA	M_3X	$(3M^+, X^{3-})$	Li_3N
IIA	VA	M_3X_2	$(3M^{2+}, 2X^{3-})$	Ca_3P_2
IIIA	VA	MX	(M^{3+}, X^{3-})	AlP

Properties of Ionic Compounds :

(i) The ionic substances are good conductors of heat and electricity in molten state or aqueous medium. In both these states, the lattice is broken and ions are free to conduct electricity and heat.

(ii) Due to stability of lattice, ionic compounds have high melting and boiling points.

(iii) The bond in ionic compounds is non-directional. In these compounds, each ion (cation or anion) has a uniformly distributed electric field, so one can not predict whether a particular ion is bonded to this or that ion.

(iv) These are soluble in polar solvents like water, which acts as a dielectric (*dielectric is a material which weakens the electric field*). When the electric field is weakened, the ions are relatively free to go in water.

COVALENT BONDING Section - 3

Certain elements which have high ionisation energies are incapable of transferring electrons and other having low electron affinities, fail to take up electrons. The atoms of such elements share their electrons with the atoms of other elements (and sometimes among themselves) in such a manner that both the atoms form complete outer shell. In this manner they achieve stability. Such an association through sharing of electron pairs among atoms of different or of same kinds is known as Covalent Bond. This was proposed by G.N. Lewis.