Subject – Chemistry
Year/Semester – 2
CEMA –CC-2-4-TH

IONIC BONDING (Part 1)
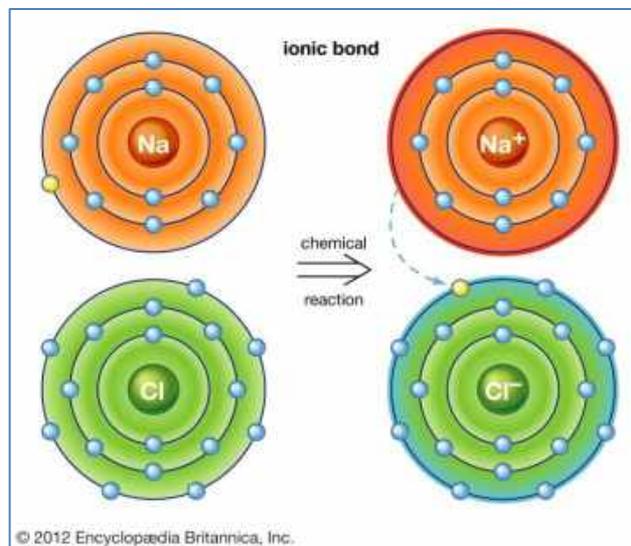
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INTRODUCTION -

➢ In chemistry, an **ionic compound** is a chemical compound composed of ions held together by electrostatic forces termed ionic bonding.

➢ The compound is neutral overall, but consists of positively charged ions called cations and negatively charged ions called anions.

➢ Individual ions within an ionic compound usually have multiple nearest neighbours, so are not considered to be part of molecules, but instead part of a continuous three- dimensional network, usually in a crystalline structure.

The Crystal Lattice Structure of Ionic Compounds
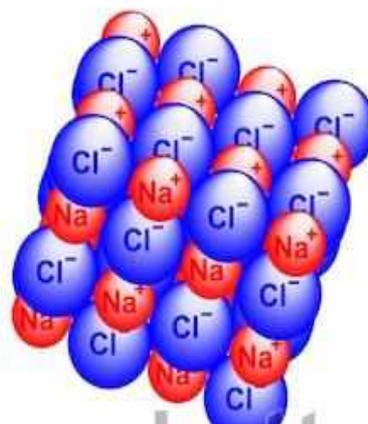
* Ions in a compound are forming crystal as a result of their arrangement in a lattice structure.

Chloride Ion

Ionic Bond

Sodium Ion
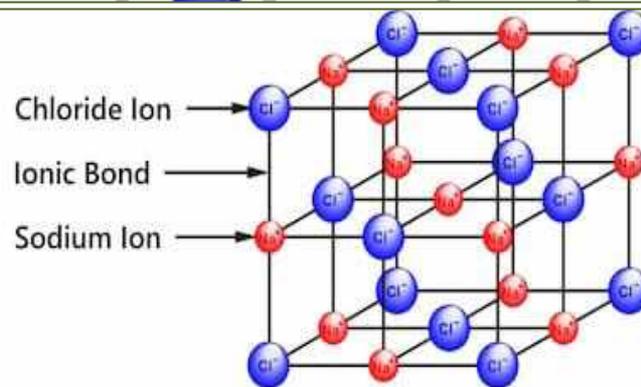
Sodium Chloride Lattice Structure

Properties

➤ They form crystals.

➤ They have high melting points and high boiling points. High temperatures are required to overcome the attraction between the positive and negative ions in ionic compounds. Therefore, a lot of energy is required to melt ionic compounds or cause them to boil.

➤ They have higher enthalpies of fusion and vaporization than molecular compounds.

➤ They are hard and brittle. Ionic crystals are hard because the positive and negative ions are strongly attracted to each other and difficult to separate, however, when pressure is applied to an ionic crystal then ions of like charge may be forced closer to each other. The electrostatic repulsion can be enough to split the crystal, which is why ionic solids also are brittle.

➤ They conduct electricity when they are dissolved in water.
When ionic compounds are dissolved in water, the dissociated ions are free to conduct electric charge through the solution. Molten ionic compounds (molten salts) also conduct electricity.

➤ They are good insulators.
Although they conduct in molten form or in aqueous solution, ionic solids do not conduct electricity very well because the ions are bound so tightly to each other.

Factors Influencing the Formation of Ionic Bond:

➢ **Ionization energy:** The lesser the ionization energy, the greater is the ease of the formation of a cation.

➢ **Electron affinity:** The higher the energy released during this process, the easier will be the formation of an anion.

➢ **Lattice energy:** The higher the lattice energy, the greater is the tendency of the formation of an ionic bond. The higher the charges on the ions and smaller the distance between them, the greater is the force of attraction between them.

Lattice Energy

➤ The **lattice energy** of a crystalline solid is a measure of the energy released when 1mole of the crystalline substance is formed from the free gaseous ions. This is also the energy required to split 1 mole of the crystalline substance into the free gaseous ions. It is a measure of the cohesive forces that bind ions. Lattice energy is relevant to many practical properties including solubility, hardness, and volatility.

➤ The experimental value for the lattice energy can be determined using the Born–Haber cycle.

➤ The lattice energy is exothermic, i.e., the value of $\Delta H_{lattice}$ is negative

➤ It can also be calculated (predicted) using the Born–Landé equation as the sum of the electrostatic potential energy, calculated by summing interactions between cations and anions, and a short-range repulsive potential energy term.

The magnitude of the lattice energy of an ionic compound depends on the nature of the packing of the ions in the crystal and is determined by charge and size of the ions. It increases with increasing charge on the ions and decreases with increasing size of the ions..

Hence, the lattice energy can be expressed as

$$U = \frac{N_A M z^+ z^- e^2}{4\pi\varepsilon_o r}\left(1 - \frac{1}{n}\right)$$

Born–Landé equation

N =   Avogadro number

Z+e, z-e = charge on cation anion respectively

r =   distance of closest approach between the nuclei of two
         oppositely charged ionsin the lattice.

A =   Madelung constant, which is characteristic of the geometry
         of the lattice

ε_0 =   permittivity of free space

n =   Born exponent, , typically a number between 5 and 12,
         determined experimentally by measuring
         the compressibility of the solid, or derived theoretically

*Ref. for derivation of Born–Landé equation

General and Inorganic Chemistry by Prof. R.P. Sarkar, Part 1

Solvation energy:

The change in Gibbs energy when an ion or molecule is transferred from a vacuum (or the gas phase) to a solvent. The main contributions to the solvation energy come from:

i) the cavitation energy of formation of the hole which preserves the dissolved species in the solvent.

ii) the orientation energy of partial orientation of the dipoles;

iii) the isotropic interaction energy of electrostatic and dispersion origin.

iv) the anisotropic energy of specific interactions, *e.g.* hydrogen bonds, donor-acceptor interactions *etc*.

To be continued...