Class ⇒ B.Sc. (Part-II) Subsidiary
Subject ⇒ Chemistry
Chapter ⇒ Solid state
Topic ⇒ Lattice energy and Born-Haber cycle

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Lattice Energy of an ionic crystal (Born – Haber cycle)

The amount of energy released when cations and anions in their gaseous state are brought together from infinite separation to form a crystal is called lattice Energy.

$$M^+ + X^- \xrightarrow{-U} MX \quad ; U = \text{Lattice energy}$$

e.g. $Na^+ + Cl^- \longrightarrow NaCl$

Experimentally, the lattice enthalpy of an ionic compound is determined by using the Born – Haber cycle.

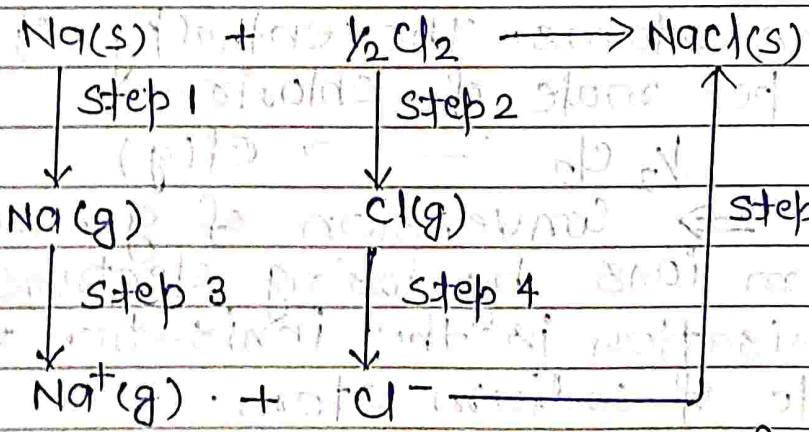

fig :- A Born-Haber cycle for the formation of NaCl crystal from its elements.

The positive and negative ion in an ionic crystal are held together by electrostatic forces.

Determination of lattice Energy

The formation of an ionic solid from its elements can be thought of as occurring directly in one step or indirectly as the sum of the series of steps.

Let us illustrate by taking example of NaCl.

Enthalpy change for direct formation ⇒ The enthalpy change for the direct formation of sodium chloride from sodium metal and chlorine is −411 KJ.

$$Na(s) + \frac{1}{2}(Cl_2) \longrightarrow NaCl(s) \quad \Delta H^\circ = -411\,KJ$$

Enthalpy change by indirect steps ⇒ The direct enthalpy change of NaCl is equal to enthalpy changes of five steps by which the formation of NaCl can be accomplished.

Step 1 ⇒ Conversion of sodium metal to gaseous atoms (sublimation)

$$Na(s) \longrightarrow Na(g) \quad \Delta H_1^\circ = +108\,KJ$$

Step 2 ⇒ Dissociation of chlorine molecules to chlorine atoms. The enthalpy of dissociation is 121 KJ per mole of chlorine.

$$\frac{1}{2}Cl_2 \longrightarrow Cl(g) \quad \Delta H_2^\circ = +121\,KJ$$

Step 3 ⇒ Conversion of gaseous atom to sodium ions by losing electrons. The enthalpy of Ionisation is the ionisation energy, 495 KJ/mole of sodium atom.

$$Na(g) \longrightarrow Na^+(g) + e^- \quad \Delta H_3^\circ = +495\,KJ$$

Step 4 ⇒ Chlorine atoms gain an electron to form chloride ions. The energy released is the electron affinity of chlorine −348 KJ

$$Cl + e^- \longrightarrow Cl^-(g) \quad \Delta H_4^\circ = -348\,KJ$$

Step 5 ⇒ Sodium and chloride ions get together

and form the crystal lattice. The energy released in this process is the negative of lattice energy.

$$Na^+_{(g)} + Cl^-_{(g)} \longrightarrow NaCl_{(s)} \quad \Delta H^\circ_5 = -(\text{lattice energy})$$

The lattice energy can be calculated by equating the enthalpy of formation of NaCl, -411 kJ, to the sum of the enthalpy changes for five steps.

$$\Delta H^\circ_1 + \Delta H^\circ_2 + \Delta H^\circ_3 + \Delta H^\circ_4 + \Delta H^\circ_5 = -411 \text{ kJ}$$

$$108 \text{ kJ} + 121 \text{ kJ} + 495 \text{ kJ} - 348 \text{ kJ} - \text{lattice energy} = -411 \text{ kJ}$$

By solving this equation, we get

$$\text{Lattice energy} = +787 \text{ kJ mol}^{-1}$$

The cycle of changes shown in figure is called the Born-Haber cycle.

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