Answer on Question#38444 - Chemistry - Physical Chemistry

Question:
Born Haber Cycle

Answer:
It is a series of steps (chemical processes) used to calculate the lattice energy of ionic solids, which is difficult to determine experimentally. You can think of BH cycle as a special case of Hesse's law, which states that the overall energy change in a chemical process can be calculated by breaking down the process into several steps and adding the energy change from each step.

To understand the BH cycle fully let us define the meaning of lattice energy first.

It is the energy released (exothermic, energy will have a negative value!) when a metal ion in its gaseous state combines with a nonmetal anion in its gaseous state to form an ionic solid. The magnitude of the lattice energy relates to how stable the ionic solid is. A larger value indicates a more stable ionic compound.

The energy released in the following processes is called is called lattice energy:

$Li^+(g) + F^-(g)$ -> $LiF(s)$ LE = -1047kJ

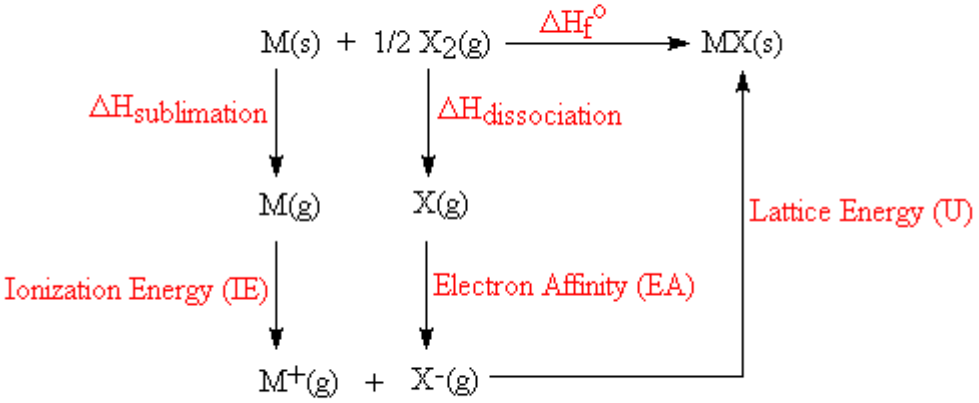
$Mg^{2+}(g) + O^{2-}(g)$ -> $MgO(s)$ LE = -3916kJ

$$LE = \frac{kQ1Q2}{r}$$

where k is a constant, Q_1 and Q_2 are the charges on the cation and anion respectively, and r is the inter-nuclear distance.

The diagram below is the Born-Haber cycle for the formation of an ionic compound from the reaction of an alkali metal (Li, Na, K, Rb, Cs) with a gaseous halogen (F_2, Cl_2). The Born-Haber thermochemical cycle is named after the two German physical chemists, Max Born and Fritz Haber, who first used it in 1919.

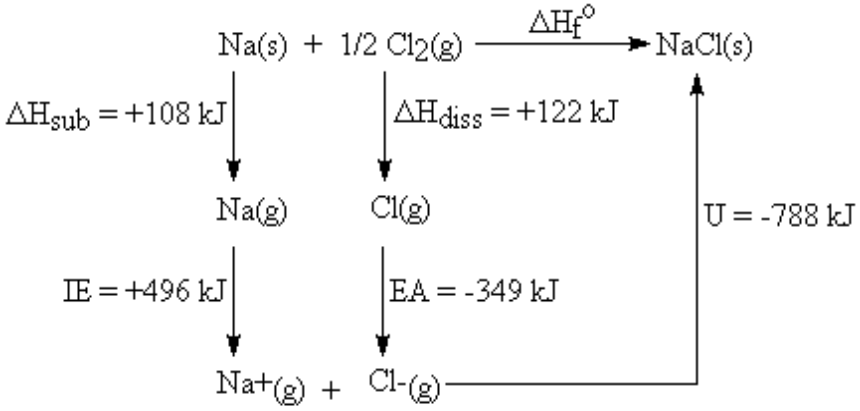
Born - Haber Cycle



$$\Delta H_f^\circ = \Delta H_{sub} + IE + \Delta H_{diss} + EA + U$$

The enthalpy change in the formation of an ionic lattice from the gaseous isolated sodium and chloride ions is -788 kJ/mole. That enthalpy change, which corresponds to the reaction $Na^+(g) + Cl^-(g) \longrightarrow NaCl(s)$, is called the lattice energy of the ionic crystal. Although the lattice energy is not directly measurable, there are various ways to estimate it from theoretical considerations and some experimental values. For all known ionic crystals, the lattice energy has a large negative value. It is ultimately the lattice energy of an ionic crystal which is responsible for the formation and stability of ionic crystal structures.

For sodium chloride, the Born - Haber cycle is:



$$\Delta H_f^\circ = \Delta H_{sub} + IE + \Delta H_{diss} + EA + U$$

$$\Delta H_f^\circ = 108 + 496 + 122 - 349 - 788 = -411 \text{ kJ/mole}$$

A cycle of this type is an example of Hess's Law. It can be used to calculate any of the six enthalpies, given the other five.