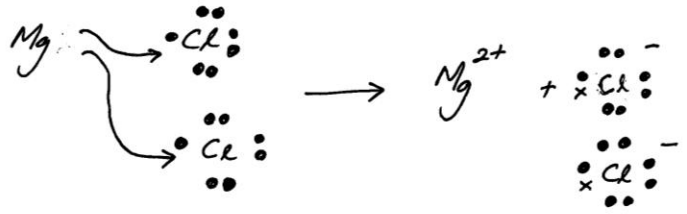
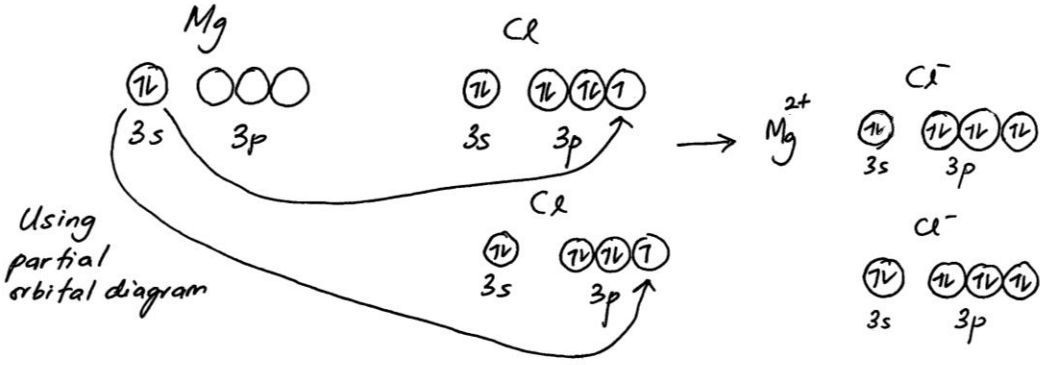
LATTICE ENERGY, $\Delta H^{o}_{lattice}$

- Ionic bonding also known as "electrovalen bonding", "polar bonding" "hetero-polar bonding".
- Ionic bonding model – transfer of electrons from metal atoms to nonmetal atoms to form ions.
- Total number of electrons lost by the metal atoms equals the total number of electrons gained by the nometal atoms.

Using Lewis symbols





- To form a ionic bond – metal atoms must have lower ionization energy [$M(g) \longrightarrow M^{+}(g) + e^{-}$] and non-metal must have higher electron affinity [$X(g) + e^{-} \longrightarrow X^{-}(g)$].

* Ionization energy – the minimum amount of energy required to remove an electron from a neutral atom = first I.E.

$$Mg(g) \longrightarrow Mg^{+}(g) + e^{-} \quad IE_1 = 738\ kJ\,mol^{-1}$$
$$[Ne]3s^2 \qquad [Ne]3s^1$$

$$Mg^{+}(g) \longrightarrow Mg^{2+}(g) + e^{-} \quad IE_2 = 1450\ kJ\,mol^{-1}$$
$$[Ne]3s^1 \qquad [Ne]$$

$$Mg^{2+}(g) \longrightarrow Mg^{3+}(g) + e^{-} \quad IE_3 = 7730\ kJ\,mol^{-1}$$
$$[Ne] \qquad [He]2s^2 2p^5$$

* Electron Affinity - The energy change when an electron is added to an atom

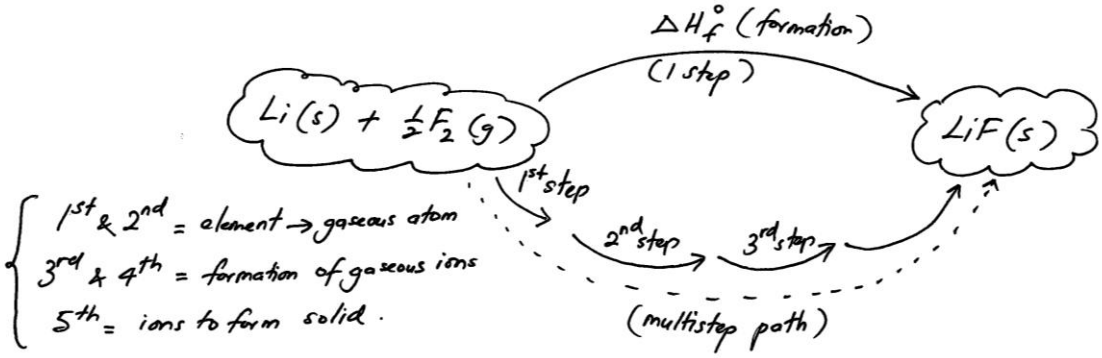
eg. $F(g) \longrightarrow F^+(g) + e^-$ $IE_1 = 168\ kJmol^{-1}$ (Ionization energy- 1st)

$F(g) + e^- \longrightarrow F^-(g)$ $EA = -322\ kJmol^{-1}$

$F^-(g) \longrightarrow F(g) + e^-$ $\Delta H = +322\ kJmol^{-1}$

LATTICE ENERGY ($\Delta H^\circ_{lattice}$)

1. Lattice Energy, $\Delta H^\circ_{lattice}$ is the enthalpy change that occurs when 1 mol of ionic solid separates into gaseous ions. $NaCl(s) \longrightarrow Na^+(g) + Cl^-(g)$
2. Lattice energy plays the important role in the formation of ionic compound, but it cannot be measured directly.
3. Lattice energy can be calculated by means of a Born-Haber Cycle (a series of chosen steps from elements to ionic solid for which all the enthalpies are known except the lattice energy)



Born-Haber Cycle : $NaCl(s)$

Step 1 :
- Bond breakage of Na

Converting 1 mol of solid Na to separate gaseous Na atoms involves <u>breaking of metallic bonds</u> so this requires energy :

$$Na(s) \longrightarrow Na(g) \qquad \Delta H_{vaporisation} = 108\ kJmol^{-1}$$

(* This process is atomization, ΔH°_{atom})

Step 2 :
- Bond breakage of Cl_2

Converting 1 mol of Cl_2 molecule to Cl atoms involves breaking covalent bonds : Bond Energy.

B.E of Cl_2 = 240 $kJmol^{-1}$

(Here we need only $\frac{1}{2}$ mol of Cl_2 to form 1 mole NaCl)

$$\tfrac{1}{2}Cl_2(g) \longrightarrow Cl(g) \; ; \; \Delta H = \tfrac{1}{2}(\text{Bond Energy})$$
$$= \tfrac{1}{2}(240)\ kJ$$
$$= 120\ kJ$$

Step 3 :
Ionization of Na

Removing the 3s electron from 1 mol of Na to form 1 mol Na^+ (requires energy)

$$Na(g) \longrightarrow Na^+(g) + e^- \qquad \Delta H_{IE_1} = 496\ kJmol^{-1}$$

Na
$1s^2 2s^2 2p^6 3s^1$

Step 4 :
Ionization of Cl

Energy is released (-ve) when chlorine atoms gain an electron - (to attain noble gas configurat

$$Cl(g) + e^- \longrightarrow Cl^-(g) \; ; \; \Delta H_{EA} = -349\ kJmol^{-1}$$

(electron affinity)

Cl
$1s^2 2s^2 2p^6 3s^1 3p^5$

Step 5. (negative of Lattice Energy)

Forming 1mol of the crystalline ionic solid, NaCl from the gaseous ions of $Na^+(g)$ & $Cl^-(g)$

$$Na^+(g) + Cl^-(g) \longrightarrow NaCl(s) : -\Delta H_{lattice} \text{ of NaCl}$$

important - negative sign.

$[\Delta H_{lattice} \text{ @ } \Delta H_{LE} \text{ @ } \Delta H_{crystal}]$

$$* \; NaCl(s) \longrightarrow Na^+(g) + Cl^-(g) : \Delta H_{lattice}$$

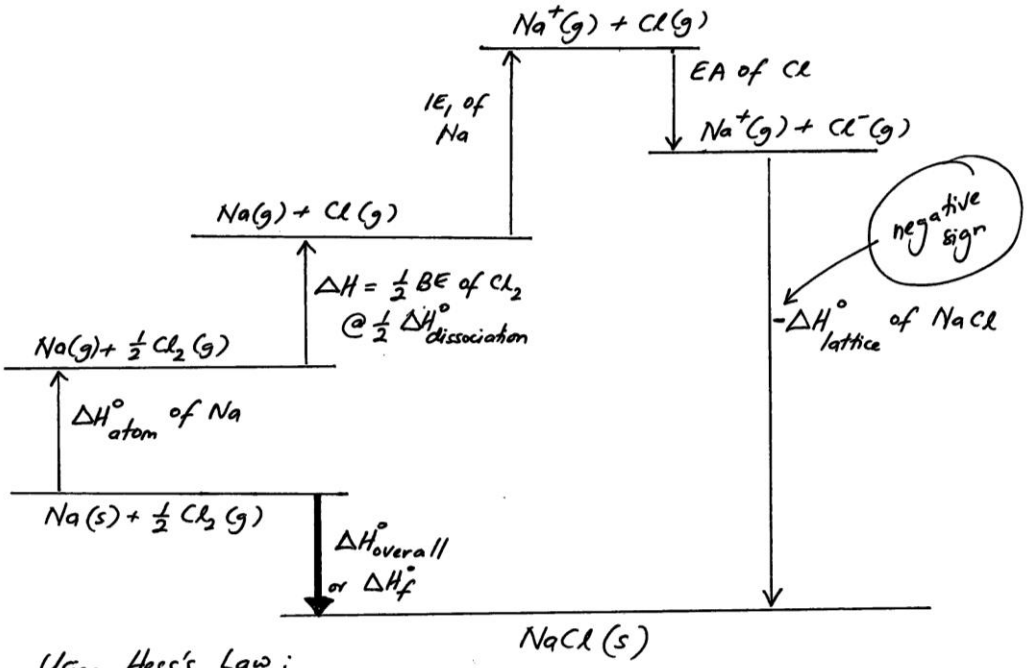
positive value.

Single step - Enthalpy change of the formation reaction.

$$Na(s) + \tfrac{1}{2}Cl_2(g) \longrightarrow NaCl(s); \; \Delta H_f^\circ = -411 \text{ kJmol}^{-1}$$

$\Delta H^\circ_{overall}$

Born - Haber Cycle for Sodium Chloride, NaCl.



Using Hess's Law:

$$\Delta H_f^\circ = \Delta H^\circ_{atom} + \tfrac{1}{2}BE + IE_1 + EA + (-\Delta H_{lattice})$$

$$-\Delta H^\circ_{lattice} = \Delta H_f^\circ - \left(\tfrac{1}{2}BE + IE_1 + EA\right)$$

$$-\Delta H^{\circ}_{lattice} = \Delta H^{\circ}_{f} - \left(\frac{1}{2}BE + IE_1 + EA\right)$$

- $\frac{1}{2}BE$: Bond energy of Cl_2
- IE_1: 1st Ionization of Na
- EA: Electron affinity of Cl

$$= (-411) - \left[\left(\frac{1}{2}\times 240\right) + 496 + (-349)\right] kJ$$

$$= -678\ kJ$$

$$\therefore \Delta H^{\circ}_{lattice} \text{ of NaCl} = +687\ kJ$$

* Note that the magnitude of the lattice energy dominates the multistep process.
* Ionic solids exists only because the lattice energy exceeds the energetically unfavorable electron transfer.
(ie. the energy required for elements to lose or gain electrons is supplied by the attraction among the ions formed)

Prepared by
V. Manoharan
vmano@usm.my
manovv1955@yahoo.com
04-6533888 ext 3566