8.3 HESS'S LAW

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Objectives:

- Define and apply Hess's Law.
- Draw or Construct the enthalpy diagram of a reaction.
- Calculate the reaction enthalpy by using
  a) algebraic method
  b) energy cycle method
  c) formula

Calculation

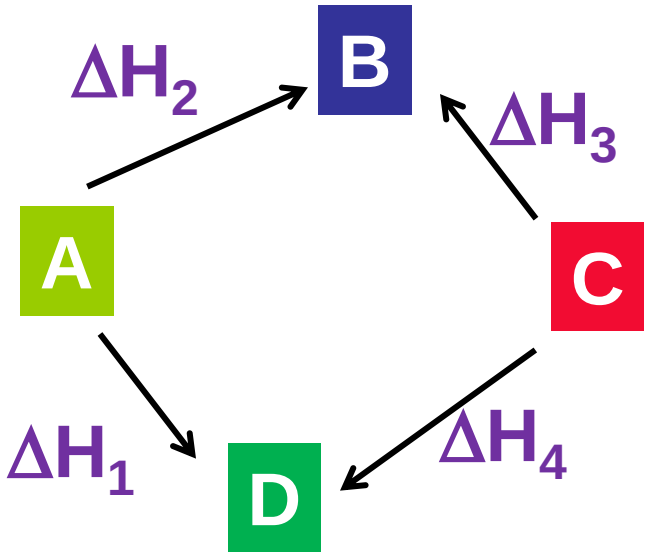
- There are generally three common ways of determining the enthalpy of a chemical reaction:
  - **Enthalpy diagram (Energy cycle method)**
  - **Algebraic method**
  - **Formula**

Points to Remember

- **Write the balanced thermochemical equations**
- **Bear in mind the characteristics of the thermochemical equation.**
- **Apply Hess's law**

HESS'S LAW

" the overall enthalpy change for a reaction is equal to the sum of the enthalpy changes for the individual steps in the reaction".



Energy cycle

Σ ΔH (route 1) = Σ ΔH (route 2)

$$-\Delta H_3 + \Delta H_4 = -\Delta H_2 + \Delta H_1$$

Enthalpy change is independent of the route taken.

Hess's law is used to calculate any unknown enthalpy which is involved in one of these steps

FORMULA METHOD

$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$ $\Delta H^0 = ?$

Given:

Compound	NH_3	NO	H_2O
ΔH^0_f (kJ mol^{-1})	-46	-242	+90

Solution:

ALGEBRAIC METHOD

$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$ $\Delta H^0 = ?$

Given:

Compound	NH_3	NO	H_2O
ΔH^0_f (kJ mol^{-1})	-46	-242	+90

Solution:

Solution:

$\frac{1}{2}N_{2\,(g)} + 3/2H_{2\,(g)} \rightarrow NH_{3\,(g)}$ $\Delta H = -46\ kJ\ mol^{-1}$ — **(1)**

$\frac{1}{2}N_{2\,(g)} + \frac{1}{2}O_{2\,(g)} \rightarrow NO_{\,(g)}$ $\Delta H = -242\ kJ\ mol^{-1}$ — **(2)**

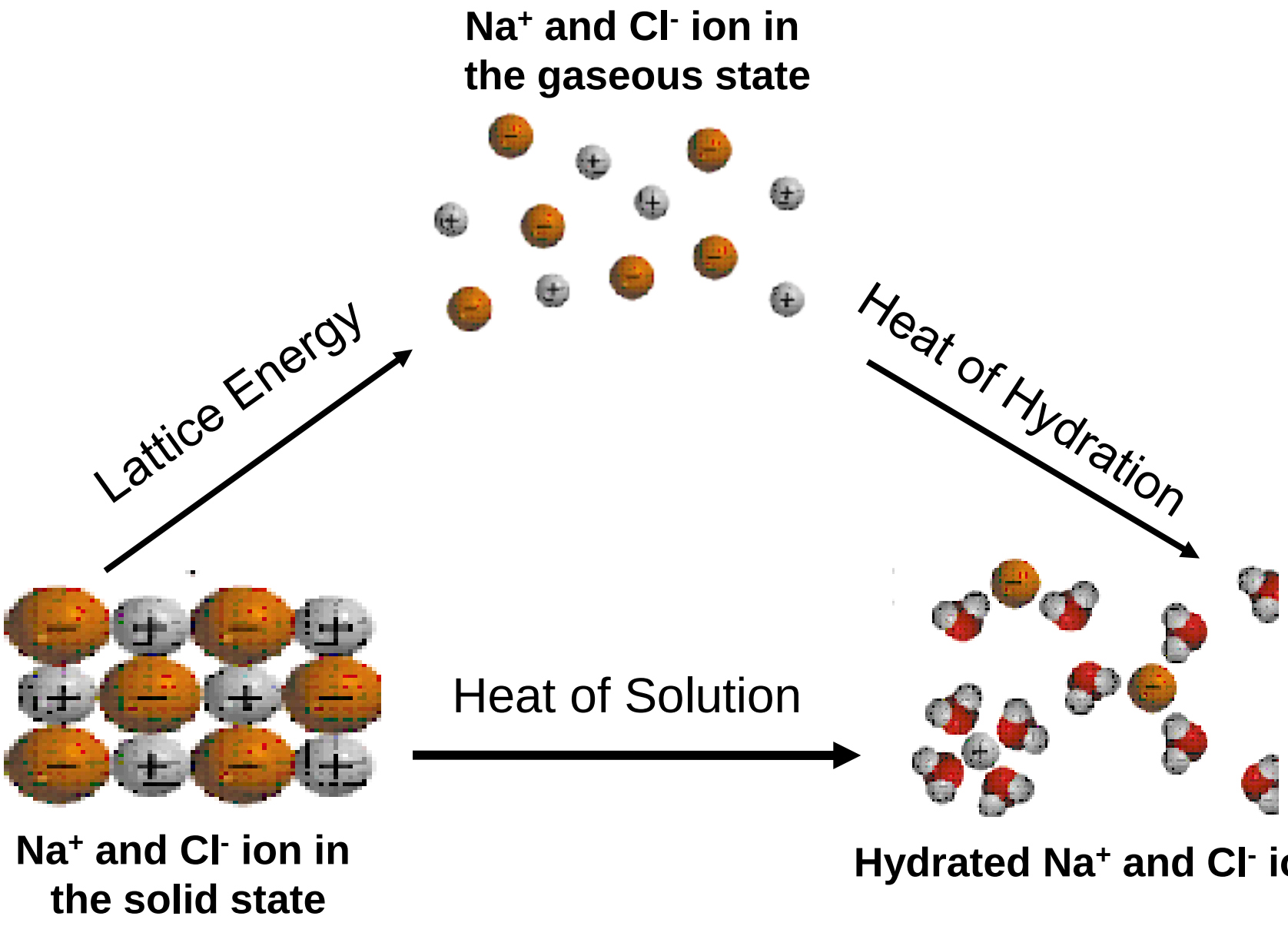
$H_{2\,(g)} + \frac{1}{2}O_{2\,(g)} \rightarrow H_2O_{\,(g)}$ $\Delta H = +90\ kJ\ mol^{-1}$ — **(3)**

CYCLE METHOD

Hydration Process of Ionic Crystal

- Na^+ and Cl^- ions in the solid crystal are separated from each other and converted to the gaseous state ($\Delta H_{lattice}$).

- The electrostatic forces between gaseous ions and **polar** water molecules cause the ions to be surrounded by water molecules (ΔH_{hydr}).


Na+ and Cl- ion in the gaseous state
Lattice Energy
Heat of Hydration
Heat of Solution
Na+ and Cl- ion in the solid state
Hydrated Na+ and Cl- ion

Enthalpy of the solution of the ionic crystal

$M^+_{(g)} + X^-_{(g)}$

$MX_{(s)}$ $M^+_{(aq)} + X^-_{(aq)}$

Enthalpy of the solution of the ionic crystal

$M^+_{(q)} + X^-_{(g)}$

$MX_{(s)}$ $M+_{(aq)} + X-_{(aq)}$

Example

Calculate the hydration energy of pottasium iodide (KI). Its enthalpy of solution is +21 kJ mol^{-1}, and its lattice energy is -642 kJ mol^{-1}.

Solution:

Energy Cycle Method

Solution:

Solution:

Check Point

1) The standard enthalpy for naphthalene, $C_{10}H_8(s)$ is

$$C_{10}H_8(s) + 12O_2(g) \longrightarrow 10CO_2(g) + 4H_2O(l)$$

$$\Delta H^o = -5156.8 \text{ kJ/mol}$$

Calculate the standard enthalpy of formation of $C_{10}H_8(s)$

Given,

$\Delta H^o_f(H_2O,l) = -285.9$ kJ/mol

$\Delta H^o_f(CO_2,g) = -393.5$ kJ/mol

$\Delta H^o_f(C_{10}H_8,s) = ???$

<+78.2 kJ/mol>

Check Point

2) Use Hess's law to determine ΔH for the reaction

$$C_3H_4(g) + 2H_2(g) \rightarrow C_3H_8(g)$$

Given that

$H_2(g) + 1/2O_2(g) \rightarrow H_2O(l)$ $\Delta H = -285.8$ kJ

$C_3H_4(g) + 4O_2(g) \rightarrow 3CO_2(g) + 2H_2O(l)$ $\Delta H = -1937$ kJ

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$ $\Delta H = -2219.1$ kJ

<-289.5 kJ>

SUMMARY

- **Hess's law**: $\Sigma \Delta H$ (route 1) = $\Sigma \Delta H$ (route 2)
- Calculation: Algebraic & Hess Cycle methods or formula