Hess's Law

We've seen that energy changes can be measured in a calorimeter. But, how can anyone measure all of the energy changes in the world? What if the reaction is unpleasant, or is an explosion, or is very complex – how can we measure the energy change then? .....We use Hess's Law to calculate the energy change from other systems.

Hess's Law:
If a reaction is carried out in a series of steps, ΔH for the reaction will be equal to the sum of enthalpy (H) changes for the individual steps.

Example 1

Calculate the enthalpy change, ΔH (in KJ), for the reaction
$2Al(s) + Fe_2O_3(s) \rightarrow 2\,Fe(s) + Al_2O_3\,(s)$ ΔH = ?

Use the enthalpy changes for the combustion of aluminum and iron:
a. $2Al\,(s) + 3/2\,O_2(g) \rightarrow Al_2O_3(s)$ ΔH = -1669.8kJ
b. $2Fe\,(s) + 3/2\,O_2(g) \rightarrow Fe_2O_3(s)$ ΔH = -824.2kJ

Solution
Notice that to achieve the desired reaction, equation (b) must be written in reverse. When this is done, be sure to change the sign of ΔH since the energy is now flowing in the opposite direction. Call this equation (c)

(c) $Fe_2O_3(s) \rightarrow 2Fe(s) + 3/2\,O_2(g)$ ΔH = $^{+}$824.2kJ

Now, add equations (a) and (c) to obtain the final answer. As in algebra, like terms cancel out.

$2Al\,(s) + \cancel{3/2\,O_2}(g) \rightarrow Al_2O_3(s)$ ΔH = -1669.8kJ
$\underline{Fe_2O_3(s) \rightarrow 2Fe(s) + \cancel{3/2\,O_2}(g)}$ ΔH = $^{+}$824.2kJ

$2Al(s) + Fe_2O_3 \rightarrow 2Fe + Al_2O_3$ ΔH = -854.6kJ

Key Points

- **If a reaction is reversed, the sign of ΔH is also reversed.**
- **The magnitude of ΔH is directly proportional to the quantities of reactants and products in a reaction. If the coefficients in a balanced reaction are multiplied by an integer, the value of ΔH is multiplied by the same integer.**

Example 2

Calculate ΔH for the reaction: $S(s) + O_2(g) \rightarrow SO_2(g)$
From the following information

(a) $S(s) + 3/2O_2(g) \rightarrow SO_3(g)$ ΔH = -395.2 kJ
(b) $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$ ΔH = -198.2kJ

Solution

To obtain the reactants and products in the desired reaction, we need to reverse equation (b) and multiply it by ½. This action reverses the sign and cuts the amount of energy by a factor of 2:

$\frac{1}{2}[2SO_3(g) \rightarrow 2SO_2(g) + O_2(g)]$ $\Delta H = \frac{{}^{+}198.2kJ}{2}$

OR

$SO_3(g) \rightarrow SO_2(g) + 1/2O_2(g)$ $\Delta H = {}^{+}99.1kJ$

Now we add this reaction to the first reaction:

$S(s) + 3/2O_2(g) \rightarrow \cancel{SO_3}(g)$ ΔH = -395.2kJ

$\cancel{SO_3}(g) \rightarrow SO_2(g) + \cancel{1/2O_2}(g)$ $\Delta H = {}^{+}99.1$ kJ

$S(s) + O_2(g) \rightarrow SO_2(g)$ **ΔH = -296.1kJ**