CAIE Chemistry A-level

5: Chemical Energetics

Notes

Enthalpy Change, ΔH

Enthalpy is the **thermal energy** stored in a chemical system. It can't be measured directly.

Reactions and Energy Changes

Chemical reactions are accompanied by energy changes (typically heat energy changes). If energy is released into the surroundings, the reaction is **exothermic and ΔH is negative**. If energy is taken in from the surroundings, the reaction is **endothermic and ΔH is positive**. The temperature of the surroundings increases during an exothermic reaction and decreases during an endothermic reaction.

Enthalpy Terms

- **Standard conditions** - temperature of 298 K (25°C), pressure of 100 kPa (1 bar), solution concentrations of 1 mol dm^{-3}. All products and reactants are in their standard states.
- **Standard enthalpy change of reaction, $\Delta H^{\ominus}_r$** - the enthalpy change that occurs when a reaction takes place in the molar quantities given in a chemical equation, all reactants and products in their standard states under standard conditions.
- **Standard enthalpy change of formation, $\Delta H^{\ominus}_f$** - the enthalpy change that takes place when one mole of a given substance is formed from its elements under standard conditions.
- **Enthalpy change of combustion, ΔH_c** - the enthalpy change when one mole of compound is burned completely in oxygen with all reactants and products in their standard state under standard conditions.
- **Standard enthalpy change of neutralisation $\Delta H^{\ominus}_{neut}$** - the enthalpy change when one mole of water is formed from a neutralisation reaction under standard conditions.

Bond energy is the energy required to break **one mole** of a given **gaseous bond** to form atoms. In the data book, bond enthalpies are quoted as a mean average because the actual enthalpy of a bond varies depending on which molecule it's in. Energy is required to break bonds so ΔH is positive (endothermic). Energy is released when bonds are made so ΔH is negative (exothermic).

Enthalpy Calculations

The enthalpy change of a reaction can be calculated using the equation below:

$$\Delta H = -mc\Delta T$$

ΔH - enthalpy change (J)
m - mass of surroundings (g)
c - specific heat capacity (J g^{-1} K^{-1})
ΔT - temperature change (K or °C)

Hess' Law

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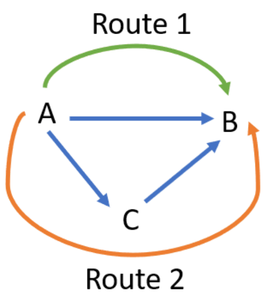
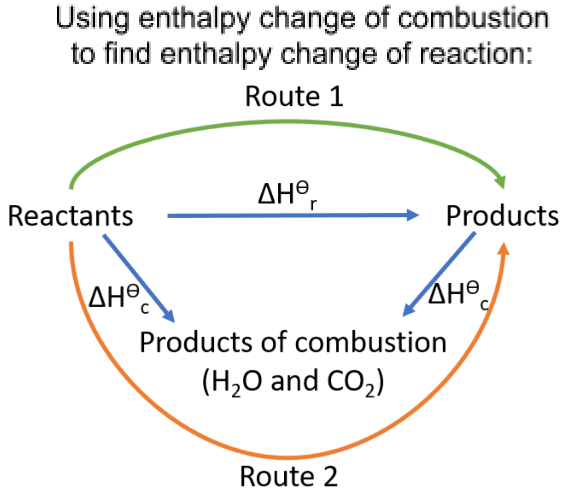
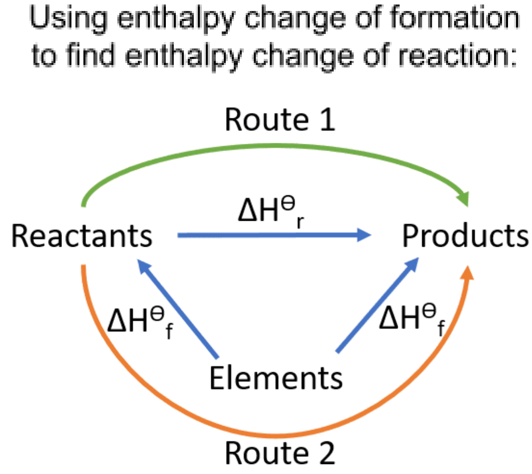
Hess' Law states that the enthalpy change that accompanies a chemical change is **independent of the route** it takes. This is because the enthalpy of the reactants and products remain the same. Any energy released when forming intermediates will be used to break bonds to allow the product to form. In the diagram below, the enthalpy charge of route 1 is the same as route 2:



Enthalpy change of formation and combustion can be used with Hess' Law to determine the enthalpy change of a reaction. It is important to note the directions of the enthalpy change arrows in the cycles below:





Average Bond Energies

Bond energies can be used to find the enthalpy change of a reaction when all reactants and products are **gaseous**.

Method 1:

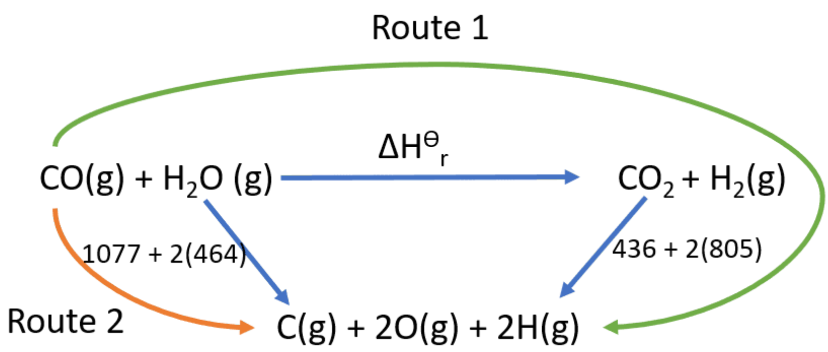
ΔH = total energy needed to break bonds - total energy made when making bonds

When totalling the energy released or made, the average bond enthalpies for each bond must be multiplied by the number of that bond present in the equation.

Method 2: Use an enthalpy cycle

E.g. $CO(g) + H_2O(g) \rightarrow CO_2(g) + H_2(g)$

Bond	**Bond enthalpy (kJ mol^{-1})**
C-O (carbon monoxide)	+1077
C=O	+805
O-H	+464
H-H	+436



Using the cycle:

$$\Delta H + 436 + 2(805) = 1077 + 2(464)$$
$$\Delta H = 1077 + 2(464) - 436 - 2(805)$$
$$\Delta H = -41 \text{ kJ mol}^{-1}$$