

WJEC Chemistry A-Level

C2.2: Thermochemistry

Detailed Notes

English Specification

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Enthalpy Changes

In a reaction, bonds are **broken** and then **made**. For bonds to be broken, **energy is taken in** from the surroundings and when bonds are formed, **energy is given out**. The overall energy change of the reaction depends on how much energy is transferred in these processes.

When energy is taken in from the surroundings, the enthalpy change is **positive**. When energy is released, the enthalpy change is **negative**.

Overall enthalpy change (ΔH) can be calculated:

$$\Delta H = \text{energy to break bonds (+ve)} + \text{energy to make bonds (-ve)}$$

If the overall enthalpy change is **positive**, the reaction is said to be **endothermic**. If **negative**, the reaction is **exothermic**.

Defining Enthalpy Changes

Enthalpies are measured under standard conditions of **100 kPa pressure** and a temperature of **298 K**. The definitions of enthalpy changes and how they are calculated vary depending on the type of reaction taking place.

Enthalpy of Formation ($\Delta_f H^\ominus$)

This is defined as:

The enthalpy change when one mole of a substance is produced from its elements under standard conditions.

Enthalpy of Combustion ($\Delta_c H^\ominus$)

This is defined as:

The enthalpy change when one mole of a substance is burned completely in oxygen under standard conditions.



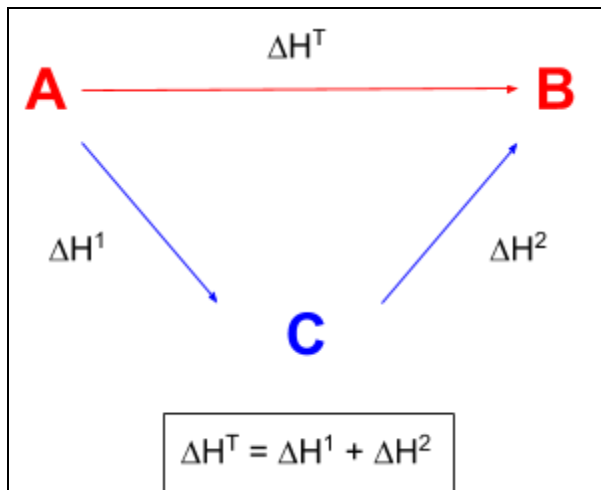


Hess's Law and Energy Cycles

Energy in a reaction system must be **conserved**, as it **cannot be created or destroyed**. Therefore the overall enthalpy change for a reaction is **the same**, regardless of the route taken.

This is **Hess's Law** and it is used to determine the enthalpy changes for reactions that cannot be found directly using an experimental method. To do this, a **triangular cycle method** is used with an **intermediate product**. The **direction of the arrows** indicates whether the values should be added or taken away. (They can be treated like vectors):

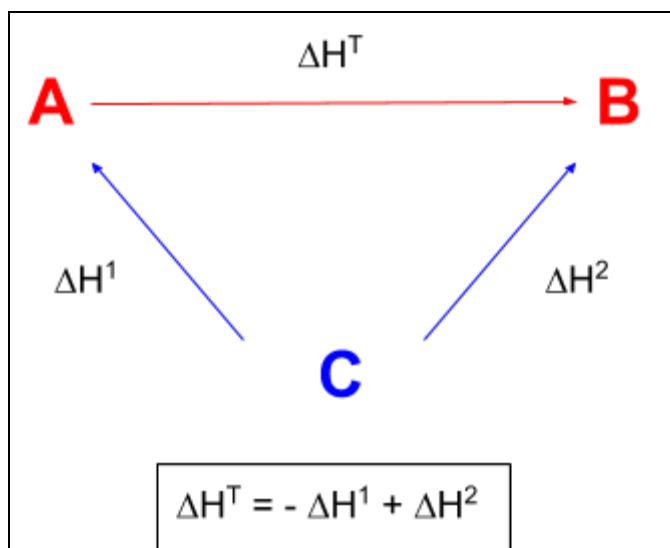
Example:



Enthalpies of Formation

Hess's law can be used to calculate an enthalpy change using given **enthalpies of formation**. When setting up the triangular diagram, the arrows **point out** from the central product C as both A and B are formed from the elements at C.

Example:



Note how ΔH^1 is subtracted as the reaction goes in the opposite direction to the arrow.

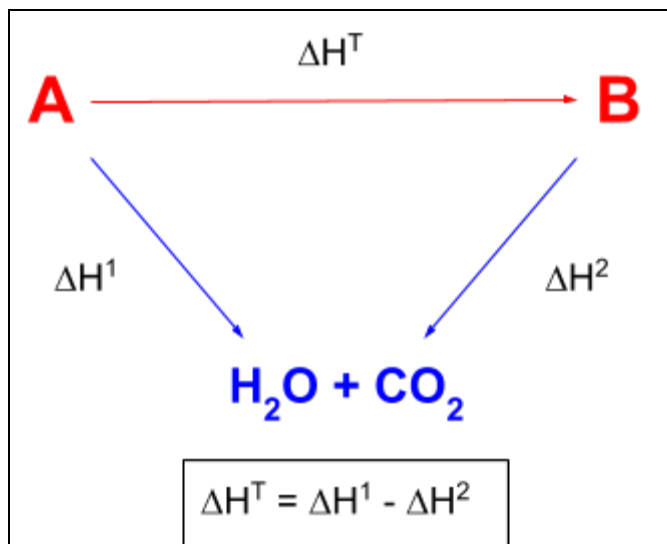




Enthalpies of Combustion

Hess's law can also be used to calculate an enthalpy change using given **enthalpies of combustion**. When setting up the triangular diagram, the arrows **point towards** the central product (which is always H_2O and CO_2) as both A and B burn to form the products at C.

Example:



Note how ΔH^2 is subtracted as the reaction goes in the opposite direction to the arrow.

Average Bond Enthalpies

Bond enthalpy data is an **averaged value** defined as:

The energy required to break one mole of the stated bond in a gaseous state, under standard conditions.

They can be used to find the **overall enthalpy change** for a reaction. The sum of the bond enthalpies of broken bonds and bonds made in the reaction are compared and the resulting value can tell you whether a reaction is exothermic or endothermic.

However, this will only be an approximation - as the average bond enthalpies will be the average bond enthalpy for a bond from a range of different compounds.

Procedures to Determine Enthalpy Changes

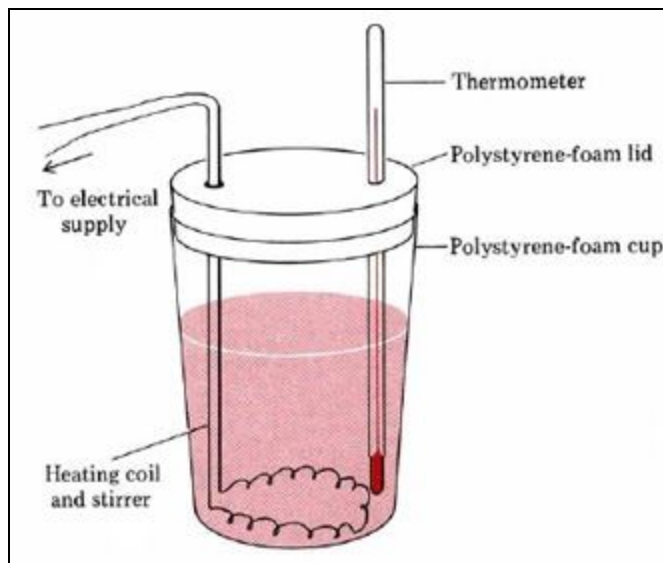
Calorimetry

Calorimetry is an experimental method for finding enthalpy change by measuring **temperature change over time**. A reaction is carried out in a **sealed, insulated container** and the temperature noted at **regular intervals** over a period of time. This type of container helps to reduce the energy lost to the surroundings.





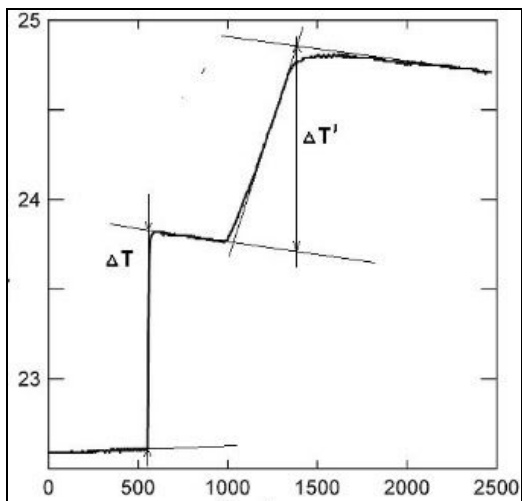
Example:



(Modified from [https://chem.libretexts.org/Bookshelves/General_Chemistry/Book%3A_ChemPRIME_\(Moore_et_al.\)/15Thermodynamics%3A_Atoms%2C_Molecules_and_Energy/15.06%3A_Measuring_the_Enthalpy_Change](https://chem.libretexts.org/Bookshelves/General_Chemistry/Book%3A_ChemPRIME_(Moore_et_al.)/15Thermodynamics%3A_Atoms%2C_Molecules_and_Energy/15.06%3A_Measuring_the_Enthalpy_Change))
John W. Moore / CC BY-SA 3.0

When observed and plotted on a graph, data can be **extrapolated** to give an accurate value for the change in temperature.

Example:



(<https://chemistry.stackexchange.com/questions/29354/Determining-enthalpy-of-neutralization-and-heat-capacity-of-calorimeter-by-over!>)
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This measured change in temperature is **proportional** to the energy change:

$$q = mc\Delta T$$

(q = energy change) (m = mass) (c = specific heat capacity) (ΔT = temperature change)





It allows the **energy in or out** of a substance of known mass to be calculated, which depends on its **specific heat capacity**, defined as:

The energy required to raise 1g of a substance by 1K without a change of state.

Using this energy value (q), **enthalpy change per mole** of substance can be calculated:

$$\Delta H = \frac{q}{\text{moles}}$$

ΔH values found using calorimetry are **never completely accurate** as energy is **easily lost** from the system through **conduction or convection** and inaccuracies in measuring temperatures.

