5.2 Hess's law

Name: _____ Class: _____ Date: _____ **Total: 20 marks**

KEY WORDS hess's law • energy cycle • enthalpy change • enthalpy change of formation • exothermic

Objective

Build the skills to answer exam questions on **Hess's law** – constructing **energy cycles** and calculating enthalpy changes from formation and combustion data.

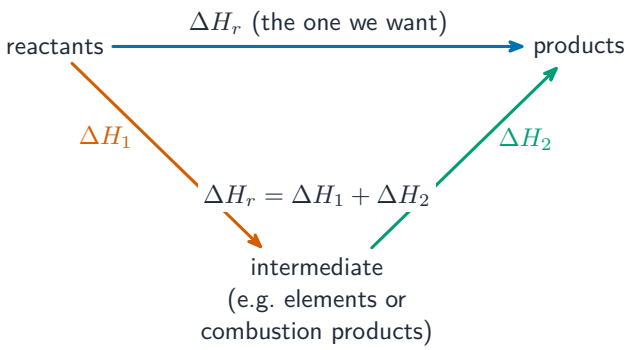
You must be able to:

- state Hess's law and construct simple energy cycles
- calculate an enthalpy change that cannot be measured directly
- use formation or combustion data (and bond energies) in a cycle

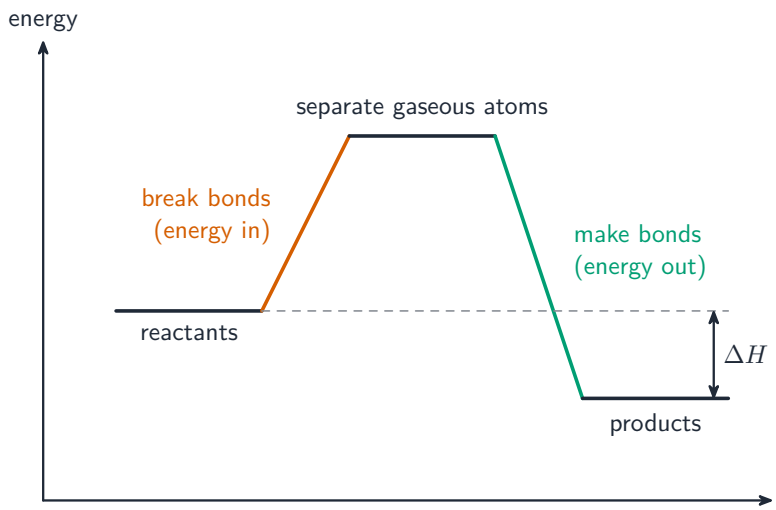
1 Key knowledge and worked examples

Hess's law

Hess's law: the total enthalpy change is the same whatever the route from reactants to products (energy is conserved).



The direct route equals the indirect route: $\Delta H_r = \Delta H_1 + \Delta H_2$



Bond energies feed an enthalpy (Hess) cycle

- **Using formation data**

$$\Delta H_r = \sum \Delta H_f(\text{products}) - \sum \Delta H_f(\text{reactants})$$

Example. $CaCO_3 \rightarrow CaO + CO_2$ (ΔH_f / kJ mol^{-1}: $CaCO_3$ -1207, CaO -635, CO_2 -394): $\Delta H_r = (-635 - 394) - (-1207) = +178$ kJ mol^{-1}.

- **Using combustion data**

$$\Delta H_r = \sum \Delta H_c(\text{reactants}) - \sum \Delta H_c(\text{products})$$

2 Practice

2.1 State **Hess's law**. [1]

2.2 Give **one** reason Hess's law is useful (something it lets you find). [1]

3 Exam-style questions

3.1 Hess's law is a consequence of: [1]

- ☐ **A** the conservation of mass
- **B** the conservation of energy
- **C** the ideal gas equation
- **D** Avogadro's law

3.2 ΔH_r from formation data is calculated as: [1]

- **A** $\sum \Delta H_f(\text{reactants}) - \sum \Delta H_f(\text{products})$
- **B** $\sum \Delta H_f(\text{products}) - \sum \Delta H_f(\text{reactants})$
- **C** $\sum \Delta H_c(\text{products}) - \sum \Delta H_c(\text{reactants})$
- **D** $mc\Delta T$

3.3 For $C_2H_4 + H_2 \rightarrow C_2H_6$, use ΔH_f (kJ mol^{-1}: C_2H_4 +52, C_2H_6 −85, H_2 0) to calculate ΔH_r. [3]

3.4 Explain why Hess's law allows the enthalpy change of formation of a compound to be found even when the reaction cannot be carried out directly. [2]

3.5 Use the standard enthalpy changes of formation below.

Compound	$\Delta H_f^\ominus$ **/ kJ mol^{-1}**
$CH_3OH(l)$	−239
$CO_2(g)$	−394
$H_2O(l)$	−286

(a) Write the equation for the complete combustion of methanol, then construct an energy cycle through the elements and use it to calculate $\Delta H_c^\ominus$ for methanol. [5]

(b) Explain why $\Delta H_f^{\ominus}$ of $O_2(g)$ is zero. [2]

(c) A school laboratory obtains -690 kJ mol^{-1}. State whether that is more or less exothermic than your answer, and give one reason for the difference. [2]

(d) State the principle that allows this calculation even though methanol is never actually burned along the route you drew. [2]