# Exercise walk-through

## Hess's law ▪ 5.2

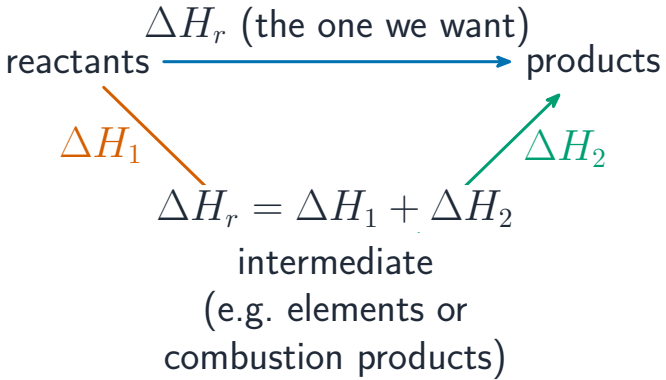
eXercise

# You must be able to

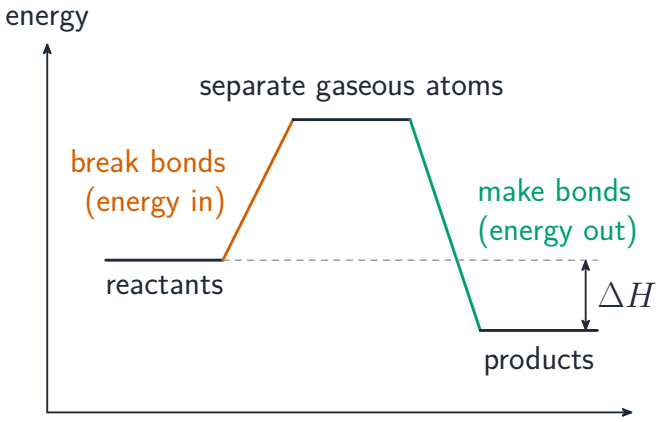
- state Hess's law and construct simple energy cycles
- calculate an enthalpy change that cannot be measured directly
- use formation or combustion data (and bond energies) in a cycle

## Method — Hess's law

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



# Method — Hess's law




*Bond energies feed an enthalpy (Hess) cycle*

## Method — Using formation data

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

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

## Method — Using combustion data

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

## Practice 2.1 ▪ 1 mark

State **Hess's law**.

# Solution 2.1

**Worked steps**

the total enthalpy change of a reaction is the same regardless of the route taken B1.

## Practice 2.2 ▪ 1 mark

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

# Solution 2.2

**Worked steps**

e.g. it lets you find an enthalpy change that cannot be measured directly / calculate $\Delta H_r$ from formation or combustion data B1.

## Exam-style 3.1 ▪ 1 mark

Hess's law is a consequence of:

**A** the conservation of mass

**B** the conservation of energy

**C** the ideal gas equation

**D** Avogadro's law

# Solution 3.1

**A** the conservation of mass

**B** the conservation of energy ✓

**C** the ideal gas equation

**D** Avogadro's law

**Worked steps**

**B**. Hess's law follows from the conservation of energy.

## Exam-style 3.2 ▪ 1 mark

$\Delta H_r$ from formation data is calculated as:

**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** $mc\Delta T$

# Solution 3.2

Method: Using formation data

**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** $mc\Delta T$

## Worked steps

**B**. $\sum \Delta H_f(\text{products}) - \sum \Delta H_f(\text{reactants})$.

## Exam-style 3.3 ▪ 3 marks

For $C_2H_4 + H_2 \rightarrow C_2H_6$, use $\Delta H_f$ (kJ mol $^1$: C H $+52$, C H $-85$, H 0) to calculate $\Delta H_r$.

# Solution 3.3

Method: Using formation data

**Worked steps**

$\Delta H_r = \Delta H_f(C_2H_6) - [\Delta H_f(C_2H_4) + \Delta H_f(H_2)]$ M1 $= -85 - (52 + 0)$ M1 $= -137$ kJ mol$^{-1}$ A1.

## Exam-style 3.4 ▪ 2 marks

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.

# Solution 3.4

Method: Hess's law

**Worked steps**

an indirect route (e.g. via combustion or formation of the elements) can be measured M1; by Hess's law the sum of the indirect steps equals the direct (unmeasurable) enthalpy change A1.