# Exercise walk-through

## Hess's Law ▪ 6.9

eXercise

# You must be able to

- combine known reactions to find an unknown $\Delta H$ (**Hess's law 盖斯定律**)
- **reverse** a reaction (flip $\Delta H$ sign) and **scale** it (multiply $\Delta H$)
- add the steps so intermediates cancel

# Method — Hess's law

$\Delta H$ depends only on the **start and end** states, not the path. So you can add known reactions to reach the target reaction, and add their $\Delta H$ values.

# Method — Two allowed moves

- **Reverse** a reaction $\rightarrow$ change the sign of its $\Delta H$.
- **Multiply** a reaction by a factor $\rightarrow$ multiply its $\Delta H$ by the same factor.

# Method — A worked combination

Target: $\mathrm{C} + \frac{1}{2}\mathrm{O}_2 \rightarrow \mathrm{CO}$. Given (1) $\mathrm{C} + \mathrm{O}_2 \rightarrow \mathrm{CO}_2$, $\Delta H = -394$; (2) $\mathrm{CO} + \frac{1}{2}\mathrm{O}_2 \rightarrow \mathrm{CO}_2$, $\Delta H = -283$. Reverse (2): $\Delta H = +283$. Add (1) + reversed (2): $\mathrm{CO}_2$ cancels, giving $\Delta H = -394 + 283 = -111$ kJ.

# Method — Cancel the intermediates

Arrange the steps so the species not in the target reaction cancel between the two sides. What remains must be the target equation.

## Practice 2.1 ▪ 1 mark

State Hess's law in one sentence.

# Solution 2.1

**Worked steps**

The enthalpy change of a reaction is the same regardless of the path taken **B1**.

# Practice 2.2 ▪ 1 mark

If reversing a reaction, what happens to $\Delta H$?

# Solution 2.2

**Worked steps**

Its sign changes $\boxed{\textbf{B1}}$.

# Practice 2.3 ▪ 1 mark

A reaction has $\Delta H = -100$ kJ. What is $\Delta H$ if you multiply the reaction by $2$?

# Solution 2.3

Method: Two allowed moves

**Worked steps**

$-200$ kJ **B1**.

# Exam-style 3.1 ▪ 1 mark

Hess's law works because $\Delta H$ is a

- **A** state function (path-independent)
- **B** rate
- **C** catalyst
- **D** temperature

# Solution 3.1

Method: Hess's law

**A** state function (path-independent) ✓

**B** rate

**C** catalyst

**D** temperature

## Worked steps

**A** — $\Delta H$ is a state function.

# Exam-style 3.2 ▪ 1 mark

Find $\Delta H$ for $N_2 + 2O_2 \rightarrow 2NO_2$ using: (1) $N_2 + O_2 \rightarrow 2NO$, $\Delta H = +180$ kJ; (2) $2NO + O_2 \rightarrow 2NO_2$, $\Delta H = -112$ kJ.

(a) State how to combine (1) and (2).

(b) Find the target $\Delta H$.

# Solution 3.2

Method: A worked combination

**Worked steps**

(a) Add (1) and (2) directly — the $2$NO cancels **B1**. (b) $\Delta H = 180 + (-112) = +68$ kJ **M1** **A1**.

# Exam-style 3.3 ▪ 4 marks

Find $\Delta H$ for $\mathrm{C} + \frac{1}{2}\mathrm{O_2} \rightarrow \mathrm{CO}$ using $\mathrm{C} + \mathrm{O_2} \rightarrow \mathrm{CO_2}$ ($-394$ kJ) and $\mathrm{CO} + \frac{1}{2}\mathrm{O_2} \rightarrow \mathrm{CO_2}$ ($-283$ kJ). Show your reasoning.

# Solution 3.3

Method: A worked combination

## Worked steps

Keep reaction 1 as is ($-394$); reverse reaction 2 ($CO_2 \to CO + \frac{1}{2}O_2$, $+283$) **M1** **M1**; add — $CO_2$ cancels, leaving $C + \frac{1}{2}O_2 \to CO$ **M1**; $\Delta H = -394 + 283 = -111$ kJ **A1**.