Exercise walk-through

Multistep Reaction Energy Profile ▪ 5.10

eXercise

You must be able to

- read a profile with **two (or more) peaks**
- identify the **rate-determining step** as the highest peak
- locate **intermediates** in the valleys between peaks

Method — Many peaks = many steps

A multi-step reaction has **one peak per step**. Between two peaks sits a **valley** — a relatively stable **intermediate**.

Method — The tallest barrier is rate-determining

The step with the **highest** peak (largest E_a measured from the valley/reactant before it) is the slowest — the **rate-determining step**.

Method — Intermediates vs transition states

- **Peaks** are transition states (unstable, cannot be isolated).
- **Valleys** between peaks are intermediates (real species, briefly formed).

Method — Overall ΔH

ΔH is still just **products minus reactants** (the start and end heights), regardless of how many peaks lie between.

Practice 2.1 ▪ 1 mark

How many steps does a profile with two peaks show?

Solution 2.1

Method: Many peaks = many steps

Worked steps

Two steps B1.

Practice 2.2 ▪ 1 mark

What does a valley between two peaks represent?

Solution 2.2

Method: Many peaks = many steps

Worked steps

An intermediate B1.

Practice 2.3 ▪ 1 mark

Which step is rate-determining on a two-peak profile?

Solution 2.3

Method: The tallest barrier is rate-determining

Worked steps

The step with the higher peak (larger activation energy) B1.

Exam-style 3.1 ▪ 1 mark

On an energy profile, an intermediate is found at a

A peak

B valley between peaks

C the reactant position

D the product position

Solution 3.1

A peak

B valley between peaks ✓

C the reactant position

D the product position

Worked steps

B — a valley between peaks.

Exam-style 3.2 ▪ 2 marks

A two-step profile: reactants at 40 kJ, peak 1 at 100 kJ, valley at 70 kJ, peak 2 at 90 kJ, products at 30 kJ.

(a) Find E_a for step 1 and for step 2 (each measured from the species before its peak).

(b) Which step is rate-determining?

(c) Find the overall ΔH.

Solution 3.2

Method: The tallest barrier is rate-determining

Worked steps

(a) step 1: $100 - 40 = 60$ kJ; step 2: $90 - 70 = 20$ kJ M1 A1. (b) Step 1 (higher barrier) B1. (c) $\Delta H = 30 - 40 = -10$ kJ B1.

Exam-style 3.3 ▪ 2 marks

Explain the difference between a transition state and an intermediate on the profile.

Solution 3.3

Worked steps

A transition state (peak) is an unstable maximum that cannot be isolated; an intermediate (valley) is a real, briefly-stable species formed between steps M1 A1.