

5.10 Energy Profiles for Many Steps

Name: _____ Class: _____ Date: _____

Total: 10 marks

KEY WORDS transition state 过渡态 • intermediates 中间体 • energy profile 能量图 • rate-determining step 决速步
• activation energy 活化能

Objective

Build the skills to answer exam questions on **energy profiles for multi-step reactions**.

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

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Many peaks = many steps

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

■ 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**.

■ Intermediates vs transition states

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

■ Overall ΔH

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

2 Practice

Now apply the methods above.

2.1 How many steps does a profile with two peaks show? [1]

2.2 What does a valley between two peaks represent? [1]

2.3 Which step is rate-determining on a two-peak profile? [1]

3 Exam-style questions

3.1 On an energy profile, an intermediate is found at a [1]

- **A** peak
 - **B** valley between peaks
 - **C** the reactant position
 - **D** the product position
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3.2 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). [2]
- (b) Which step is rate-determining? [1]
- (c) Find the overall ΔH . [1]

3.3 Explain the difference between a transition state and an intermediate on the profile.[2]

Solutions

2.1 Two steps.

2.2 An intermediate.

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

3.1 B — a valley between peaks.

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

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