Exercise walk-through

Introduction to Reaction Mechanisms ▪ 5.7

eXercise

You must be able to

- identify the **rate-determining step** 決速歩 (the slowest step)
- explain that the overall rate cannot exceed the slowest step
- check that steps add to the overall reaction

Method — The slowest step controls

A multi-step reaction goes no faster than its **slowest** step — the **rate-determining step (RDS)**. Like a slow lane on a highway, it sets the overall pace.

Method — The bottleneck idea

If step 1 is slow and step 2 is fast, the overall rate is fixed by step 1. Speeding up the fast step does nothing; you must speed up the slow one.

Method — The rate law comes from the RDS

The overall rate law is (usually) the rate law of the **rate-determining step**, written from its molecularity — provided that step's species are reactants (not intermediates).

Method — Steps must sum correctly

Whatever the speeds, the elementary steps must add up (intermediates cancelling) to the overall balanced equation.

Practice 2.1 ▪ 1 mark

What is the rate-determining step?

Solution 2.1

Worked steps

The slowest step in the mechanism, which sets the overall rate B1.

Practice 2.2 ▪ 1 mark

Step 1 is slow, step 2 is fast. Which sets the overall rate?

Solution 2.2

Worked steps

Step 1 (the slow step) B1.

Practice 2.3 ▪ 1 mark

If you speed up only the fast step, does the overall rate change much?

Solution 2.3

Method: The bottleneck idea

Worked steps

No — it is limited by the slow step B1.

Exam-style 3.1 ▪ 1 mark

The overall rate of a multi-step reaction is controlled by the

A fastest step

B slowest step

C first step always

D last step always

Solution 3.1

Method: The slowest step controls

A fastest step

B slowest step ✓

C first step always

D last step always

Worked steps

B — the slowest step.

Exam-style 3.2 ▪ 1 mark

A mechanism is: Step 1 (slow) $NO_2 + NO_2 \rightarrow NO_3 + NO$; Step 2 (fast) $NO_3 + CO \rightarrow NO_2 + CO_2$.
(a) Which step is rate-determining?
(b) Write the rate law from that step.

Solution 3.2

Worked steps

(a) Step 1 B1. (b) rate $= k[\mathrm{NO_2}]^2$ (from the slow elementary step) M1 A1.

Exam-style 3.3 ▪ 2 marks

Explain, with the highway analogy or otherwise, why speeding up a fast step does not speed up the overall reaction if another step is slow.

Solution 3.3

Method: The bottleneck idea

Worked steps

The overall reaction can only proceed as fast as its slowest bottleneck; a faster fast-step just waits on the slow step, so the total time barely changes M1 A1.