A-LEVEL CHEMISTRY • EXERCISE SHEET

26.1 Rate equations, orders of reaction and rate constants

Name: _____ Class: _____ Date: _____ **Total: 11 marks**

Objective

Build the skills to answer exam questions on **rate equations** 速率方程—**order of reaction** 反应级数, the **rate constant** 速率常数, **half-life** 半衰期, and the **rate-determining step** 决速步.

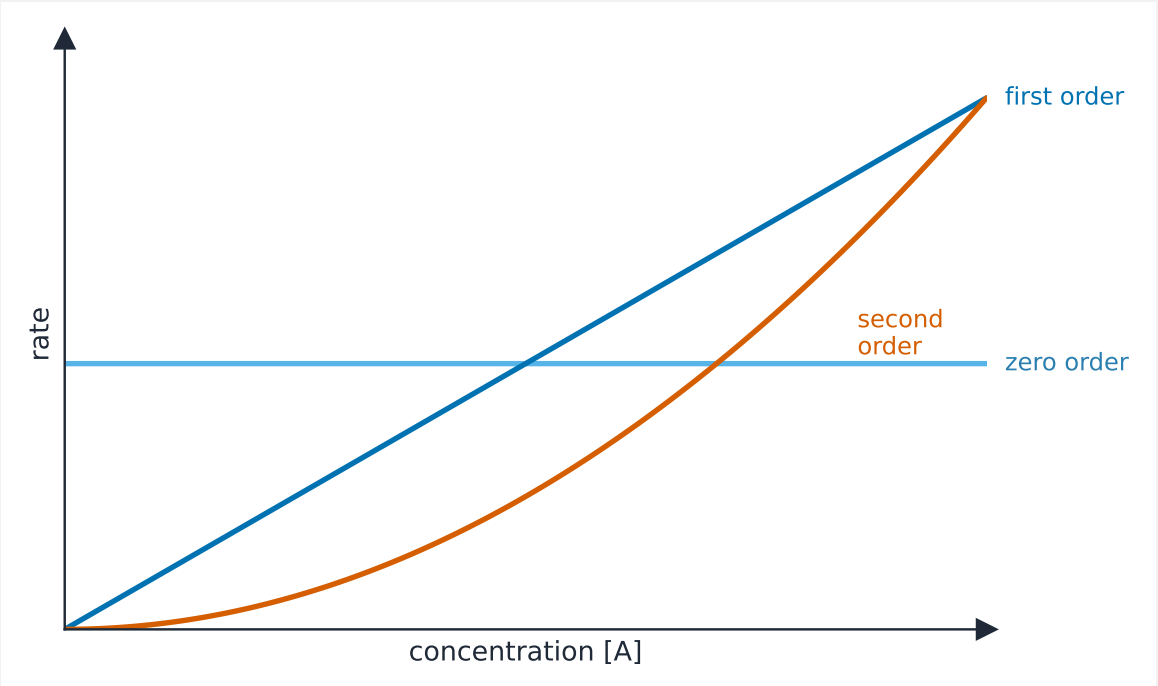
You must be able to:

- deduce orders from initial-rates data or concentration–time graphs and construct a rate equation
- use first-order half-life and calculate the rate constant
- deduce a rate equation from a mechanism and identify the rate-determining step

1 Worked examples

Rate equation and order

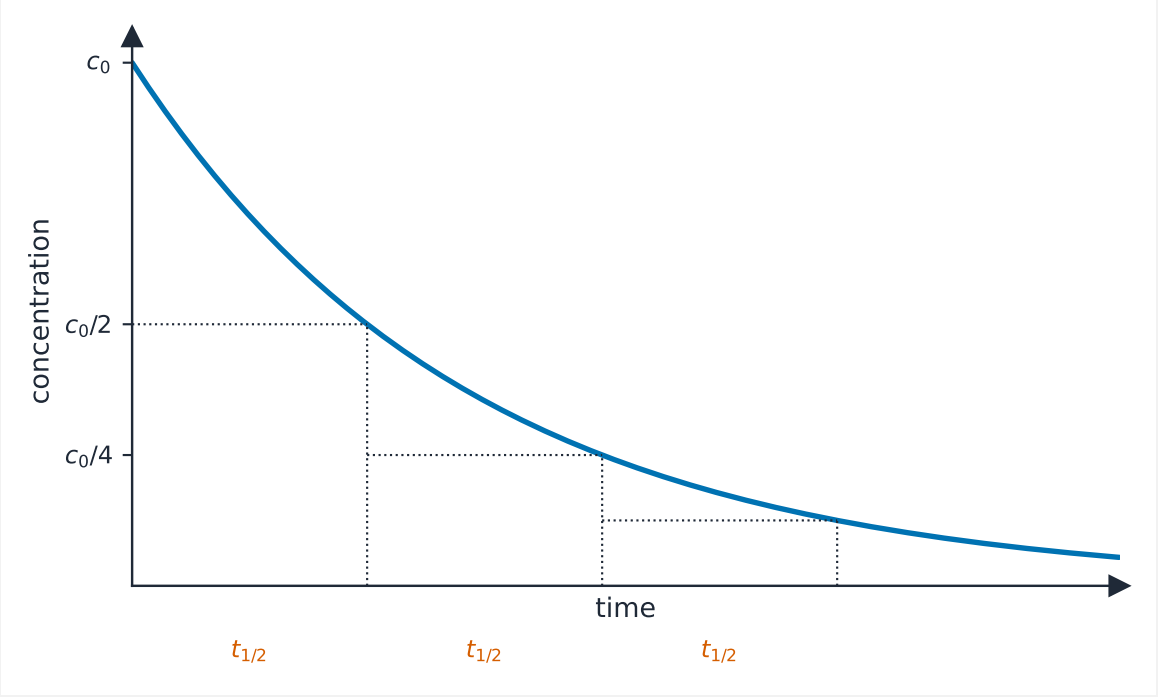
rate $= k[\mathrm{A}]^m[\mathrm{B}]^n$ —found only by **experiment**. Order $m/n = 0$, 1 or 2; overall order $= m + n$.



Deduce the order from the shape of the graphs, or from initial-rates data

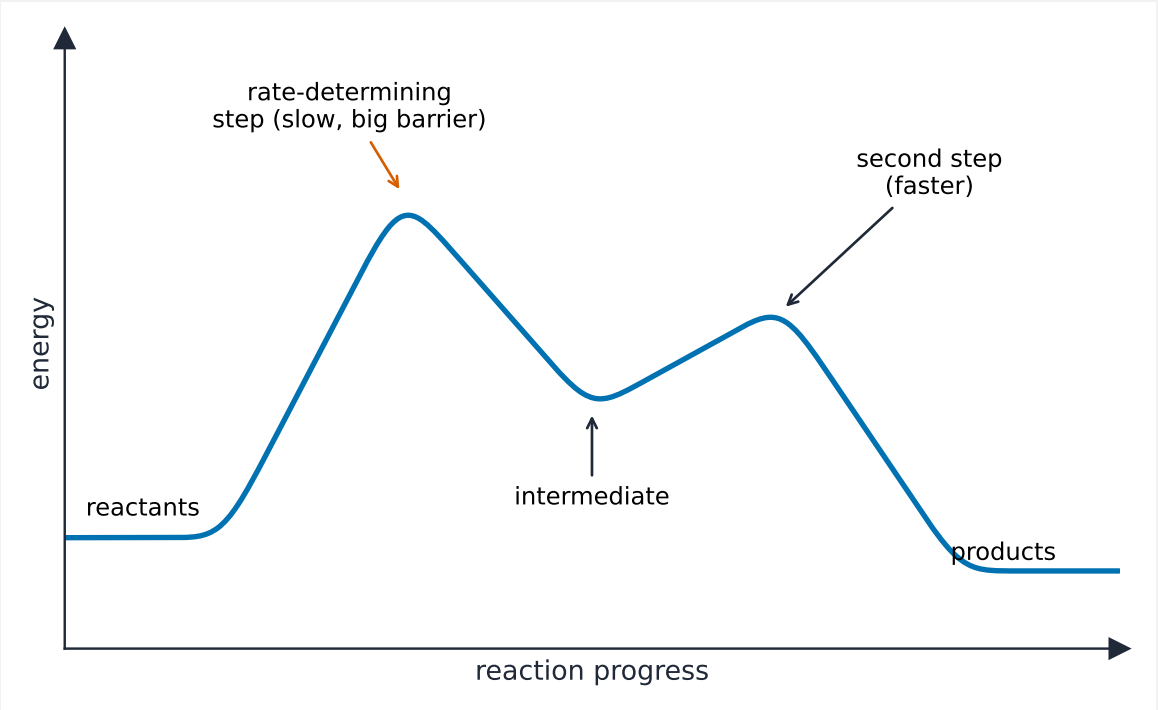
Initial rates: if doubling [A] doubles the rate → 1st order; if it quadruples → 2nd order; no change → 0 order.

Half-life and rate constant



*A first-order reaction has a **constant** half-life (independent of concentration):* $k = 0.693/t_{1/2}$

Mechanism and rate-determining step



*The rate equation reflects the species in the **rate-determining (slowest) step**; an intermediate is made then used up*

2 Practice

2.1 State what is meant by the **overall order** of a reaction. [1]

2.2 State how the half-life of a first-order reaction changes as the reaction proceeds. [1]

3 Exam-style questions

3.1 A reaction is first order in A and second order in B. Its overall order is: [1]

- **A** 1
- **B** 2
- **C** 3
- **D** 0

3.2 A first-order reaction has a half-life of 50 s. Its rate constant is ($k = 0.693/t_{1/2}$): [1]

- **A** 0.014 s^{-1}
- **B** 0.0139 s^{-1}
- **C** 36 s^{-1}
- **D** 50 s^{-1}

3.3 Experiment data for $A + B \rightarrow$ products:

[A]	[B]	initial rate
0.10	0.10	2.0×10^{-3}
0.20	0.10	4.0×10^{-3}
0.20	0.20	1.6×10^{-2}

(a) Deduce the order with respect to A and to B. [2]

(b) Write the rate equation and calculate the rate constant k (with units). [3]

3.4 The rate equation for a reaction is rate $= k[X]$. A proposed mechanism has two steps. State which step must be rate-determining and why. [2]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **26.1 Rate equations** past-paper sheet in the Library, or try these in **Practice mode**:

- 9701/41 N25 —Q3 (rate equations, orders of reaction and rate constants)
- 9701/42 N25 —Q2 (rate equations, orders of reaction and rate constants)
- 9701/44 N25 —Q4 (rate equations, orders of reaction and rate constants)

Solutions

2.1 the sum of the orders with respect to each reactant ($m + n$).

2.2 it stays constant (independent of concentration).

3.1 C. Overall order = 1 + 2 = 3.

3.2 B. $k = 0.693/50 = 0.0139\ \text{s}^{-1}$.

3.3 (a) A: doubling [A] (rows 1→2) doubles the rate → first order; B: doubling [B] (rows 2→3) makes the rate ×4 → second order.
(b) rate = $k[\text{A}][\text{B}]^2$; $k = \dfrac{2.0 \times 10^{-3}}{(0.10)(0.10)^2} = 2.0\ \text{mol}^{-2}\text{dm}^6\text{s}^{-1}$.

3.4 the first step (or whichever contains only X) must be rate-determining; because only X appears in the rate equation, so the slow step involves X.