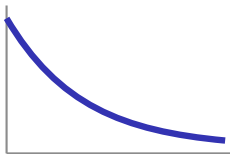


Reaction Kinetics

A-Level Chemistry ■ Topic 26

A-Level Chemistry



What we will cover

- 1 Rate equations & orders
- 2 Order graphs
- 3 Half-life & rate constant
- 4 Reaction mechanisms
- 5 Catalysts



measures gas made over time



Rate equations and orders

$$\text{rate} = k[A]^m[B]^n$$

Worked example

doubling $[A]$ doubles the rate (order 1); doubling $[B]$ quadruples it (order 2) $\Rightarrow \text{rate} = k[A][B]^2$, **overall order 3**

The **order** and **rate constant** k are found by **experiment**, not from the equation.



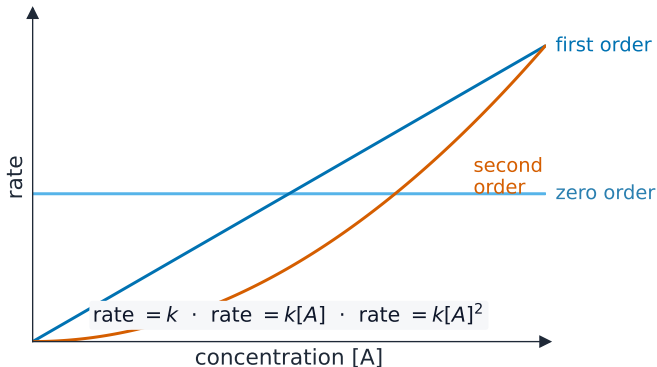
Catalyst pellets

Order graphs

Rate against concentration:

- zero order – a flat line
- first order – a straight line through the origin
- second order – an upward curve

Order graphs, in detail



Rate against concentration: zero order is a flat line, first order a straight line through the origin, second order an upward curve

Half-life and the rate constant

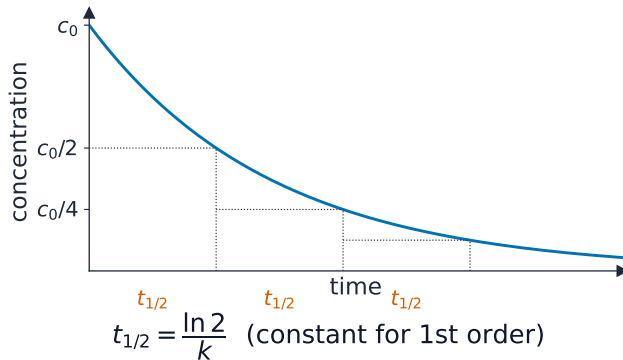
A **first-order** reaction has a **constant half-life** $t_{1/2}$.

$$k = \frac{0.693}{t_{1/2}}$$

$$t_{1/2} = 120 \text{ s}$$

$$k = \frac{0.693}{120} = 5.8 \times 10^{-3} \text{ s}^{-1}$$

A first-order reaction has a constant half-life



A first-order reaction has a constant half-life: the concentration halves in the same time $t_{1/2}$ again and again, whatever the starting value

Half-life and the rate constant, continued

For a first-order reaction the **half-life** is constant:

$$t_{1/2} = \frac{\ln 2}{k} \approx \frac{0.693}{k}$$

A constant half-life on a concentration–time graph **proves** first order. Zero-order half-life gets shorter as concentration falls; second-order half-life gets longer.

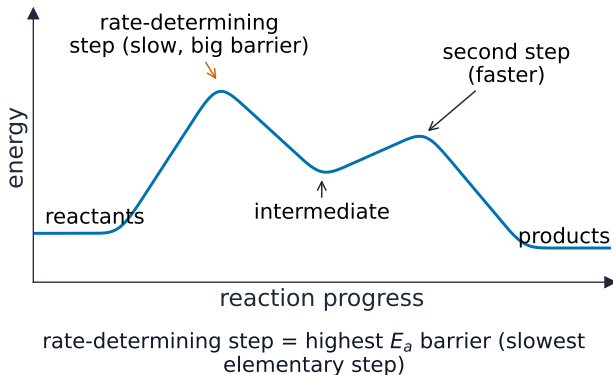


Reaction mechanisms

The slowest step is the **rate-determining step** – it controls the overall rate.

Only species up to & including it appear in the rate equation. An **intermediate** is made then used up – not in the overall equation.

Reaction mechanisms, in detail



The slowest step is the **rate-determining step** – it controls the overall rate.

Effect of temperature

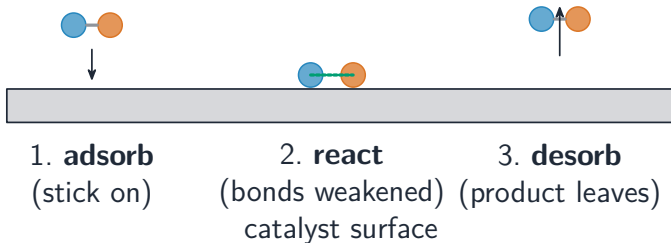
Raising the temperature increases the rate constant k (more molecules pass the activation energy), so the rate goes up.

Catalysts

A **heterogeneous catalyst** works in three stages:

- **adsorption** onto the surface
- weakened bonds react
- **desorption** of the product

A **homogeneous** one is reformed unchanged.



The two kinds of catalyst, and the rate vocabulary

heterogeneous

a **different** physical state from the reactants – iron in the Haber process, and platinum, palladium and rhodium in a catalytic converter

how it works

reactants adsorb onto the surface, react there, and desorb

homogeneous catalyst

the **same** physical state as the reactants; it is **used up in one step and remade in a later one**

order of reaction

the power to which a concentration is raised in the rate equation

the overall order

the sum of the individual orders

the initial rate

measured at $t = 0$, before any product can interfere – which is why it is used to find orders

Order is found **by experiment**, never from the balanced equation. That is the single most-tested point in this topic.

Exam tips

- Find **orders** from initial-rate data: doubling a concentration that doubles the rate is first order, quadruples it is second order, no change is zero order.
- Write $\text{rate} = k[\text{A}]^m[\text{B}]^n$ and work out the **units of** k from it.
- The **rate-determining step** contains the species (and orders) in the rate equation – use this to test a mechanism.
- A **constant half-life** means first order.



Topic 26 – key takeaways

1

Rate equation

rate = $k[A]^m[B]^n$; found by experiment

2

Orders

0 flat, 1 straight, 2 curved

3

Half-life

first order: constant $t_{1/2}$; $k = 0.693/t_{1/2}$

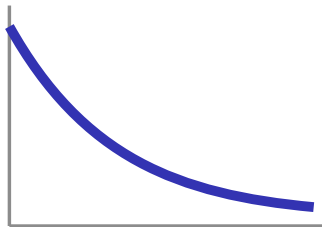
4

Mechanism

the rate-determining step controls the rate

Check yourself

- 1 How is a rate equation found?
- 2 What graph shape is a first-order rate-conc plot?
- 3 What is special about a first-order half-life?
- 4 Which step controls the overall rate?



Answers 1. by experiment 2. a straight line through the origin 3. it is constant
4. the rate-determining step