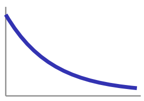
Reaction Kinetics

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

1 Rate equations

Rate equations and orders

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

Worked example

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

The **order** 反应级数 and **rate constant** 速率常数 k are found by experiment, not from the equation.

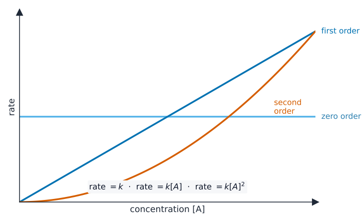
Catalyst pellets

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

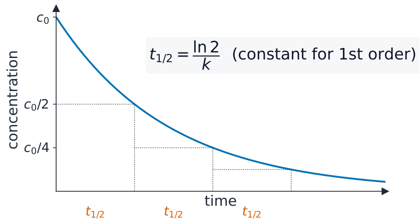
A first-order reaction has a **constant half-life** 恒定半衰期 $t_{1/2}$.

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

$t_{1/2} = 120\,\mathrm{s}$

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

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** 半衰期 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.

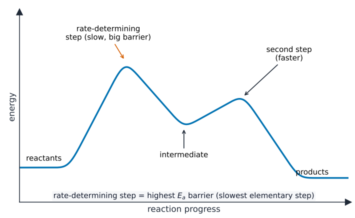
2 Mechanisms and catalysts

Reaction mechanisms

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

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

Reaction mechanisms, in detail



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

Effect of temperature

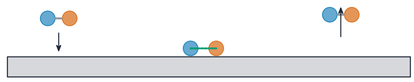
Raising the temperature increases the rate constant k (more molecules pass the activation energy), so the rate goes up.

Catalysts

A **heterogeneous catalyst** 多相催化剂 works in three stages:

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

A **homogeneous** 均相 one is reformed unchanged.



1. **adsorb** (stick on)
2. **react** (bonds weakened)
3. **desorb** (product leaves)

catalyst surface

The two kinds of catalyst, and the rate vocabulary

heterogeneous 多相催化剂	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 均相催化剂	the same physical state as the reactants; it is used up in one step and remade in a later one
order of reaction 反应级数	the power to which a concentration is raised in the rate equation
the overall order 总级数	the sum of the individual orders
the initial rate 初始速率	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 rate $= k[\mathrm{A}]^m[\mathrm{B}]^n$ 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.

3 Recap

Topic 26 – key takeaways

1 Rate equation
rate $= k[\mathrm{A}]^m[\mathrm{B}]^n$; found by experiment

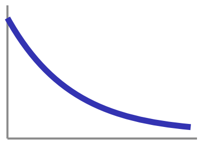
2 Orders
0 flat, 1 straight, 2 curved

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