Exercise walk-through

Concentration Changes Over Time ▪ 5.3

eXercise

You must be able to

- recognise a **zero, first, or second order** reaction from a straight-line plot
- use the **half-life 半衰期** of a first-order reaction
- know which graph is linear for each order

Method — Which plot is linear

- **Zero order**: $[\mathrm{A}]$ vs t is a straight line.
- **First order**: $\ln[\mathrm{A}]$ vs t is a straight line.
- **Second order**: $\dfrac{1}{[\mathrm{A}]}$ vs t is a straight line.

Test data by seeing which plot gives a straight line — that reveals the order.

Method — The slope gives k

For first order, $\ln[\mathrm{A}] = -kt + \ln[\mathrm{A}]_0$: the slope is $-k$. For second order, the slope of $\frac{1}{[\mathrm{A}]}$ vs t is $+k$.

Method — First-order half-life

A first-order reaction has a **constant** half-life:

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

It takes the same time to halve, over and over — independent of the starting amount.

Method — A worked half-life

If $k = 0.0347\ \text{s}^{-1}$, then $t_{1/2} = \dfrac{0.693}{0.0347} = 20\ \text{s}$.

Practice 2.1 ▪ 1 mark

Which plot is linear for a first-order reaction?

Solution 2.1

Method: Which plot is linear

Worked steps

$\ln[\mathrm{A}]$ vs t B1.

Practice 2.2 ▪ 2 marks

Find the half-life of a first-order reaction with $k = 0.100\ \text{s}^{-1}$.

Solution 2.2

Method: First-order half-life

Worked steps

$$t_{1/2} = \frac{0.693}{0.100} = 6.93 \text{ s} \quad \text{M1 A1}.$$

Practice 2.3 ▪ 1 mark

For a first-order reaction, does the half-life depend on the starting concentration?

Solution 2.3

Method: First-order half-life

Worked steps

No — it is constant (independent of starting concentration) B1.

Exam-style 3.1 ▪ 1 mark

A plot of $\frac{1}{[A]}$ vs time is linear. The reaction is

A zero order

B first order

C second order

D third order

Solution 3.1

Method: Which plot is linear

A zero order

B first order

C second order ✓

D third order

Worked steps

C — a linear $\frac{1}{[A]}$ plot means second order.

Exam-style 3.2 ▪ 2 marks

A first-order reaction has a half-life of 30 s.
(a) Find the rate constant k.
(b) What fraction of the reactant remains after 60 s?

Solution 3.2

Method: First-order half-life

Worked steps

(a) $k = \dfrac{0.693}{30} = 0.0231\ \text{s}^{-1}$ M1 A1. (b) 60 s is two half-lives, so $\left(\frac{1}{2}\right)^2 = \frac{1}{4}$ remains M1 A1.

Exam-style 3.3 ▪ 2 marks

A student plots $[\mathrm{A}]$, $\ln[\mathrm{A}]$, and $\dfrac{1}{[\mathrm{A}]}$ against time; only the $\ln[\mathrm{A}]$ plot is straight. State the order and how to find k from the graph.

Solution 3.3

Method: Which plot is linear

Worked steps

First order **M1**; the slope of the $\ln[\mathrm{A}]$ vs t line is $-k$ **A1**.