

5.3 Concentration Over Time

Name: _____ Class: _____ Date: _____

Total: 11 marks

KEY WORDS half-life 半衰期 • rate constant 速率常数 • rate law 速率方程

Objective

Build the skills to answer exam questions on **concentration over time** — the integrated rate laws.

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

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Which plot is linear

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

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

■ The slope gives k

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

■ 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.

■ **A worked half-life**

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

2 Practice

Now apply the methods above.

2.1 Which plot is linear for a first-order reaction? [1]

2.2 Find the half-life of a first-order reaction with $k = 0.100 \text{ s}^{-1}$. [2]

2.3 For a first-order reaction, does the half-life depend on the starting concentration? [1]

3 Exam-style questions

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

- **A** zero order
 - **B** first order
 - **C** second order
 - **D** third order
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3.2 A first-order reaction has a half-life of 30 s.

(a) Find the rate constant k . [2]

(b) What fraction of the reactant remains after 60 s? [2]

3.3 A student plots $[A]$, $\ln[A]$, and $\frac{1}{[A]}$ against time; only the $\ln[A]$ plot is straight. State the order and how to find k from the graph. [2]

Solutions

2.1 $\ln[A]$ vs t .

2.2 $t_{1/2} = \frac{0.693}{0.100} = 6.93 \text{ s}.$

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

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

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

3.3 First order; the slope of the $\ln[A]$ vs t line is $-k$.