

Integrated Rate Laws and Reaction Mechanisms

Concentration and time, half-lives and mechanisms

Name _____ Class _____ Date _____

INTEGRATED RATE LAWS

Zero: $[A] = [A]_0 - kt \cdot t_{1/2} = [A]_0 \div 2k$ First: $\ln[A] = \ln[A]_0 - kt \cdot t_{1/2} = \ln 2 \div k$

Second: $1/[A] = 1/[A]_0 + kt \cdot t_{1/2} = 1 \div (k[A]_0)$

Use the same time unit for k and t. Show units on every quantity.

A. Understanding

1. Define (a) half-life (b) elementary step (c) rate-determining step (d) intermediate.

2. For zero-, first- and second-order reactions, state which plot against time is a straight line, what its slope equals, and the units of k (concentration in M, time in s).

B. Calculations

3. A drug is removed from the body by first-order kinetics with a half-life of 4.00 h. A patient takes 200. mg. (a) Find k. (b) How much remains after 10.0 h?

4. A first-order reaction has $k = 0.0200 \text{ min}^{-1}$. How long does it take for $[A]$ to fall from 0.800 M to 0.200 M ?

5. A second-order reaction has $k = 0.150 \text{ M}^{-1} \text{ s}^{-1}$ and $[A]_0 = 0.0500 \text{ M}$. Find (a) the first half-life (b) $[A]$ after $200. \text{ s}$.

6. A zero-order decomposition on a metal surface has $k = 2.50 \times 10^{-3} \text{ M/s}$ and $[A]_0 = 0.500 \text{ M}$. Find (a) the half-life (b) the time for all of A to be used up.

C. Order from data

7. For a reaction $A \rightarrow \text{products}$: $[A] = 0.400, 0.300, 0.225$ and 0.169 M at $t = 0, 100, 200$ and 300 s . Show that the reaction is first order and find k .

D. Mechanisms

8. A proposed mechanism is: step 1 $\text{NO}_2\text{Cl} \longrightarrow \text{NO}_2 + \text{Cl}$ (slow); step 2 $\text{NO}_2\text{Cl} + \text{Cl} \longrightarrow \text{NO}_2 + \text{Cl}_2$ (fast). (a) Write the overall equation. (b) Identify the intermediate. (c) Write the rate law predicted by this mechanism.

E. Challenge

9. A second-order reaction has $k = 0.0500 \text{ M}^{-1} \text{ s}^{-1}$ and $[\text{A}]_0 = 0.100 \text{ M}$. Calculate the first half-life ($0.100 \text{ M} \rightarrow 0.0500 \text{ M}$) and the second half-life ($0.0500 \text{ M} \rightarrow 0.0250 \text{ M}$). How could this pattern be used to identify a second-order reaction?