

Rate laws, orders and half-lives

AP Chemistry · Worksheet

Name: _____ Date: _____ Class: _____

These twenty problems train you to read rate laws, extract reaction orders from initial-rate data and graphs, and use integrated rate laws and half-lives. They move from recall to multi-step reasoning in the style of AP Chemistry Unit 5 and first-year university kinetics. Show every substitution and write units with each answer.

Level: AP Chemistry · **Curriculum:** AP Chem Unit 5

Problem 1 Reading a rate law (easy)

A reaction obeys $\text{rate} = k[\text{A}]^2[\text{B}]$.

1. State the order in A, the order in B and the overall order.
2. Give the units of k when concentrations are in M and time in s.
3. State what happens to the rate if [B] is doubled.

Problem 2 Units of the rate constant (easy)

Wanjiru in Nairobi lists three reactions: (X) $\text{rate} = k$, (Y) $\text{rate} = k[\text{P}]$, (Z) $\text{rate} = k[\text{Q}]^2$.

1. Give the units of k for each.
2. Identify which reaction has a constant rate as the reactant is used up.

Problem 3 What the change in rate tells you (easy)

Three separate experiments change one concentration at a time.

1. Doubling [X] doubles the rate. State the order in X.
2. Tripling [Y] multiplies the rate by 9. State the order in Y.
3. Doubling [Z] leaves the rate unchanged. State the order in Z.

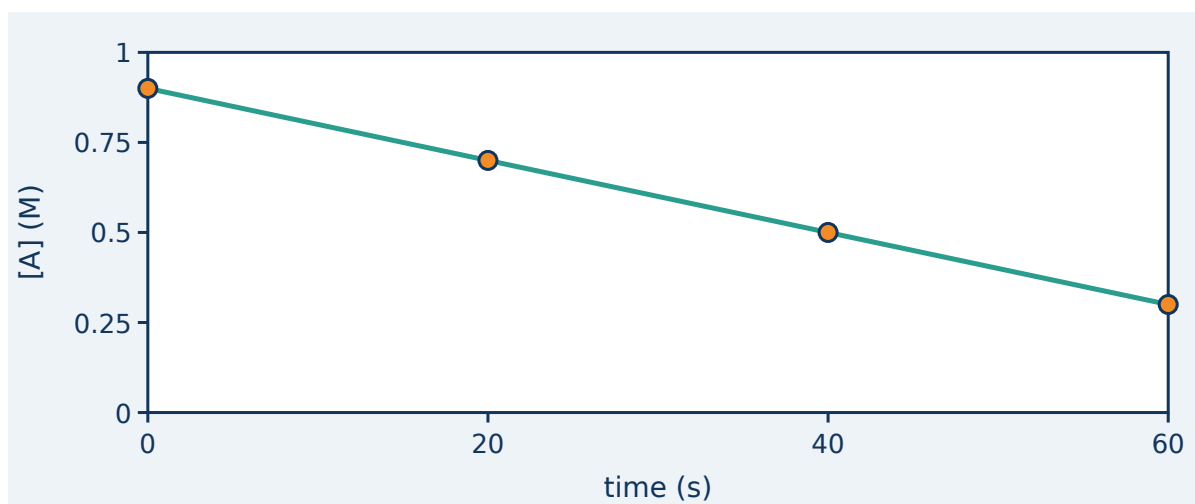
Problem 4 Half-life of a first-order reaction (easy)

A first-order reaction has $k = 0.0462 \text{ min}^{-1}$.

1. Calculate the half-life.
2. Determine the fraction of the reactant left after 45.0 min.

Problem 5 Reading a concentration-time graph (easy)

The graph shows [A] for a decomposition on a hot metal surface.

*Data for the problem.*

1. Describe the shape and name the order.
2. Determine the slope.
3. State the value and units of k .

Problem 6 Choosing the straight-line plot (easy)

Diego in Texas finds that a plot of $\ln[A]$ against time is a straight line with a slope of -0.025 s^{-1} .

1. State the order.
2. State k with units.
3. Calculate the half-life.

Problem 7 Second-order half-life (easy)

A second-order reaction has $k = 0.25 \text{ M}^{-1} \text{ s}^{-1}$.

1. Calculate the half-life when $[A]_0 = 0.40 \text{ M}$.
2. Calculate the half-life when $[A]_0 = 0.20 \text{ M}$.
3. Explain why the second answer is larger.

Problem 8 Initial rates with two reactants (medium)

For $P + Q \rightarrow \text{products}$: Experiment 1 has $[P] = 0.20 \text{ M}$, $[Q] = 0.10 \text{ M}$, rate = $3.0 \times 10^{-4} \text{ M/s}$. Experiment 2 has $[P] = 0.40 \text{ M}$, $[Q] = 0.10 \text{ M}$, rate = $6.0 \times 10^{-4} \text{ M/s}$. Experiment 3 has $[P] = 0.40 \text{ M}$, $[Q] = 0.30 \text{ M}$.

1. Determine the order in P.
2. Experiment 3 gives a rate of $5.4 \times 10^{-3} \text{ M/s}$; determine the order in Q.
3. Write the rate law and calculate k .

Problem 9 Time for a first-order change (medium)

A first-order reaction has $k = 2.5 \times 10^{-3} \text{ s}^{-1}$ and $[A]_0 = 0.60 \text{ M}$.

1. Calculate the time for $[A]$ to fall to 0.15 M .

2. Check your answer using half-lives.

Problem 10 Finding k from two measurements (medium)

A first-order reaction falls from 0.80 M to 0.50 M in 120 s.

1. Calculate k .
2. Calculate the half-life.
3. Predict $[A]$ after 300 s.

Problem 11 Pesticide breakdown on a farm (medium)

A pesticide in soil breaks down by a first-order process with a half-life of 8.0 days. A field has 5.0 mg/kg.

1. Calculate k in day^{-1} .
2. Calculate the time for the level to fall to 1.0 mg/kg.

Problem 12 Second-order concentration (medium)

A second-order reaction has $k = 0.80 \text{ M}^{-1} \text{ s}^{-1}$ and $[A]_0 = 0.50 \text{ M}$.

1. Calculate $1/[A]_0$.
2. Calculate $[A]$ after 25 s.

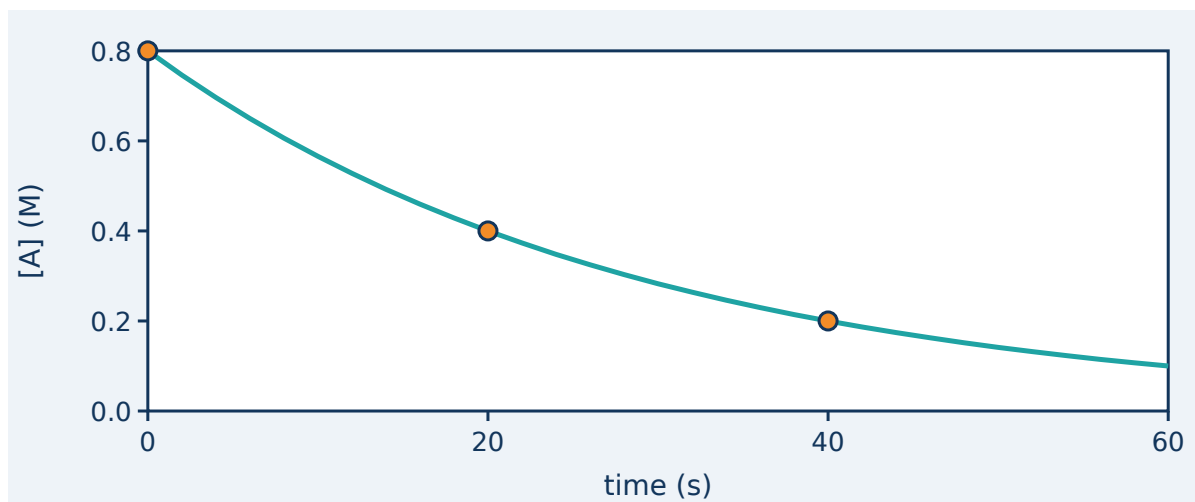
Problem 13 Zero-order surface reaction (medium)

Ammonia decomposes on a hot tungsten wire with a zero-order rate. $k = 1.5 \times 10^{-4} \text{ M s}^{-1}$ and $[\text{NH}_3]_0 = 0.0600 \text{ M}$.

1. Calculate the time for the reaction to finish.
2. Calculate the half-life.
3. Explain why the rate does not depend on $[\text{NH}_3]$.

Problem 14 Reading half-lives from a graph (medium)

The graph shows $[A]$ against time for a decomposition.



Concentration of A with time.

1. Determine two successive half-lives.
2. State the order and justify it.
3. Calculate k .
4. Predict $[A]$ at 60 s.

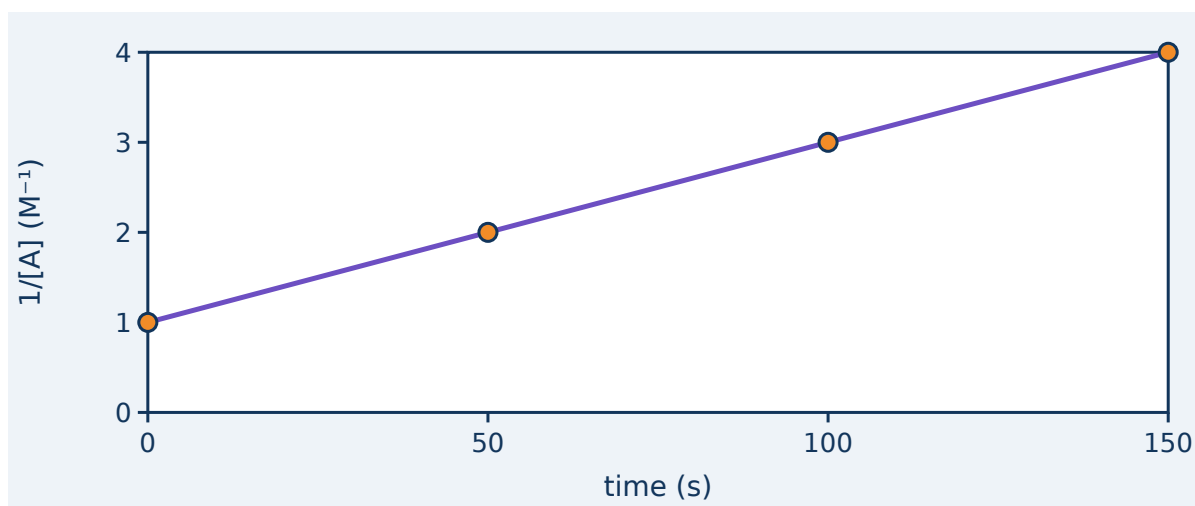
Problem 15 Converting the rate constant (medium)

Mei in Singapore finds $k = 3.6 \times 10^{-2} \text{ min}^{-1}$ for a first-order reaction.

1. Convert k to s^{-1} .
2. Calculate the half-life in minutes and in seconds.

Problem 16 Deciding the order from data (hard)

Data for the decomposition of A: $t = 0, 50, 100, 150 \text{ s}$; $[A] = 1.00, 0.50, 0.33, 0.25 \text{ M}$.



Reciprocal concentration against time.

1. Calculate $1/[A]$ at each time.
2. Decide whether the order is zero, first or second.
3. Determine k .
4. Show that the half-life from $[A]_0 = 1.00 \text{ M}$ agrees with the data.

Problem 17 Three reactants (hard)

For $X + Y + Z \rightarrow \text{products}$, initial rates are: (1) $[X] = 0.10, [Y] = 0.10, [Z] = 0.10 \text{ M}$, rate $4.0 \times 10^{-3} \text{ M/s}$; (2) $[X] = 0.20, [Y] = 0.10, [Z] = 0.10$, rate 8.0×10^{-3} ; (3) $[X] = 0.10, [Y] = 0.20, [Z] = 0.10$, rate 1.6×10^{-2} ; (4) $[X] = 0.10, [Y] = 0.10, [Z] = 0.30$, rate 4.0×10^{-3} .

1. Determine the order in each reactant.
2. Write the rate law and calculate k with units.
3. Predict the rate for $[X] = 0.30, [Y] = 0.05, [Z] = 0.50 \text{ M}$.

Problem 18 Gas pressure and first order (hard)

A gas-phase decomposition is first order with $k = 1.2 \times 10^{-3} \text{ s}^{-1}$ in a sealed vessel. The partial pressure of the reactant starts at 80.0 kPa.

1. Calculate the time for it to fall to 25.0 kPa.
2. Calculate the percentage that has reacted after 10.0 min.
3. Explain why pressure can replace concentration here.

Problem 19 Pseudo-first-order kinetics (hard)

The rate law is $\text{rate} = k[\text{A}][\text{B}]$. In a run, $[\text{A}]_0 = 0.0010 \text{ M}$ and $[\text{B}]_0 = 0.50 \text{ M}$. The plot of $\ln[\text{A}]$ against time has a slope of $-3.0 \times 10^{-3} \text{ s}^{-1}$.

1. Explain why $[\text{B}]$ stays almost constant.
2. Calculate k .
3. Predict the slope magnitude when $[\text{B}]_0 = 0.25 \text{ M}$.
4. Calculate the half-life of A in that run.

Problem 20 Two first-order reactions racing (hard)

Reaction 1 has a half-life of 10 min and reaction 2 has a half-life of 40 min; both are first order and start at the same concentration.

1. Calculate the fraction left of each after 40 min.
2. Determine the time at which the concentration of reaction 2 is four times that of reaction 1.