

Orders, rate constants and activation energy

Chemistry grades 11-12 (A Level · IB · Class 11-12) · Worksheet

Name: _____ Date: _____ Class: _____

These 20 problems train you to work with rate equations: deriving orders from initial rates and graphs, finding units and values of k , using half-lives, applying the Arrhenius equation and linking mechanisms to rate-determining steps. They progress from reading equations to multi-step data analysis.

The level suits IB Chemistry, A Level, CBSE Class 11-12 and WAEC/NECO senior students. Show every substitution and keep units throughout.

Level: Chemistry grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB R2.2

Problem 1 Rate words (easy)

Aarav in Pune revises kinetics.

1. Define the rate of a reaction.
2. State the usual unit of rate for a reaction in solution.
3. State two things that change the value of the rate constant k and one that does not.

Problem 2 Reading a rate equation (easy)

The rate equation for $2\text{NO} + \text{O}_2 \rightarrow 2\text{NO}_2$ is $\text{rate} = k[\text{NO}]^2[\text{O}_2]$.

1. State the order with respect to NO and to O_2 , and the overall order.
2. State the effect on rate of doubling $[\text{O}_2]$ alone and of doubling $[\text{NO}]$ alone.
3. Deduce the units of k .

Problem 3 Doubling and tripling (easy)

Chiamaka in Lagos completes a table. State the factor by which the rate changes for each case.

1. Zero order in X: $[\text{X}]$ doubled, then tripled.
2. First order in X: $[\text{X}]$ doubled, then tripled.
3. Second order in X: $[\text{X}]$ doubled, then tripled.
4. Second order in X: $[\text{X}]$ halved.

Problem 4 Units of k (easy)

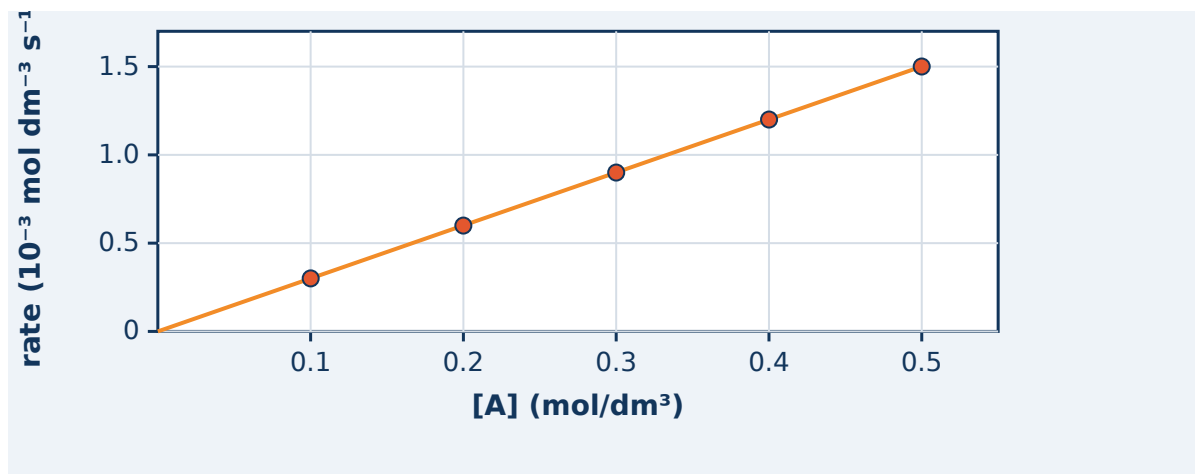
Derive the units of k for a reaction that is:

1. zero order overall
2. first order overall

3. second order overall
4. third order overall

Problem 5 Rate against concentration (easy)

Kofi in Accra measures initial rates at five concentrations of A.



Rate against concentration of A.

1. State the order with respect to A and justify it.
2. Calculate k from the gradient.
3. Use the line to find the rate at $[A] = 0.35 \text{ mol/dm}^3$.

Problem 6 Using a rate equation (easy)

A reaction is second order in A with rate = $k[A]^2$ and $k = 0.030 \text{ dm}^3 \text{ mol}^{-1} \text{ s}^{-1}$.

1. Calculate the rate when $[A] = 0.15 \text{ mol/dm}^3$.
2. Calculate the rate when $[A] = 0.30 \text{ mol/dm}^3$.
3. State how the two rates compare and why.

Problem 7 Initial rates, one reactant (medium)

Emma in Leeds studies the decomposition of a compound X. $[X] = 0.20, 0.40$ and 0.80 mol/dm^3 give initial rates of 1.6×10^{-3} , 6.4×10^{-3} and $2.56 \times 10^{-2} \text{ mol dm}^{-3} \text{ s}^{-1}$.

1. Deduce the order with respect to X.
2. Write the rate equation.
3. Calculate k with its units.

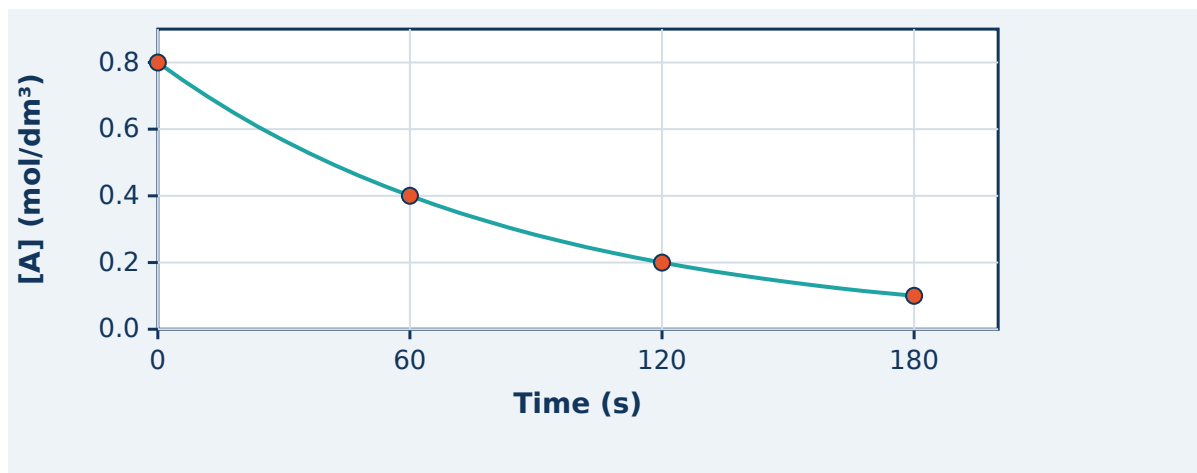
Problem 8 Half-life calculation (medium)

A first order reaction has $k = 4.6 \times 10^{-3} \text{ s}^{-1}$.

1. Calculate the half-life.
2. Calculate the time for the concentration to fall to 12.5 % of its initial value.
3. Calculate the percentage of reactant left after one half-life and after two.

Problem 9 Half-lives from a graph (medium)

The graph shows [A] against time.



Concentration of A against time.

1. Find the time for [A] to fall from 0.80 to 0.40 and from 0.40 to 0.20 mol/dm³.
2. Deduce the order.
3. Calculate k.

Problem 10 Two reactants (medium)

Experiments for $A + B \rightarrow \text{products}$: (1) $[A] = 0.050$, $[B] = 0.020$, rate 1.0×10^{-5} ; (2) $[A] = 0.100$, $[B] = 0.020$, rate 4.0×10^{-5} ; (3) $[A] = 0.050$, $[B] = 0.060$, rate 3.0×10^{-5} (concentrations in mol/dm³, rates in mol dm⁻³ s⁻¹).

1. Deduce the order in A and in B.
2. Write the rate equation and the overall order.
3. Calculate k with units.

Problem 11 Slow step (medium)

A proposed mechanism for $\text{NO}_2 + \text{CO} \rightarrow \text{NO} + \text{CO}_2$ is: step 1 (slow) $\text{NO}_2 + \text{NO}_2 \rightarrow \text{NO}_3 + \text{NO}$; step 2 (fast) $\text{NO}_3 + \text{CO} \rightarrow \text{NO}_2 + \text{CO}_2$.

1. Show that the steps add to the overall equation and identify the intermediate.
2. Write the rate equation predicted by the mechanism.
3. Explain why CO does not appear in it.

Problem 12 Doubling every ten degrees (medium)

Mei in Singapore finds that the rate constant of a reaction doubles when the temperature rises from 298 K to 308 K.

1. Calculate $1/298 - 1/308$.
2. Calculate the activation energy.
3. State two assumptions of this calculation.

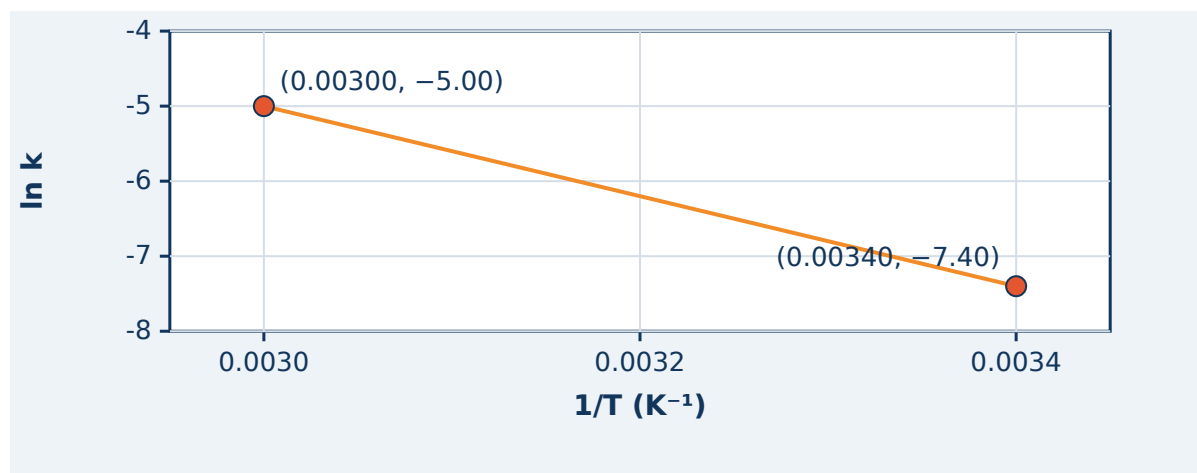
Problem 13 Effect of a catalyst (medium)

At 300 K a catalyst lowers the activation energy from 75.0 to 50.0 kJ/mol.

1. Calculate the change in E_a in J/mol.
2. Calculate the factor by which k increases (assume A is unchanged).
3. Explain in terms of particles why the rate increases.

Problem 14 Reading an Arrhenius plot (medium)

Bilal in Lahore plots $\ln k$ against $1/T$.



Arrhenius plot of $\ln k$ against $1/T$.

1. Calculate the gradient.
2. Calculate E_a .
3. Calculate $\ln A$ and A (units of k are s^{-1}).

Problem 15 A drug in the body (medium)

A drug leaves the blood by a first order process with half-life 6.0 h.

1. Calculate k in h^{-1} .
2. Calculate the percentage left after 15 h.
3. Calculate the time for 90 % to be removed.

Problem 16 Three reactants (hard)

For $\text{P} + \text{Q} + \text{R} \rightarrow \text{products}$ the initial rates ($\text{mol dm}^{-3} \text{s}^{-1}$) are: (1) $[\text{P}] = [\text{Q}] = [\text{R}] = 0.10$, rate 3.0×10^{-5} ; (2) $[\text{P}] = 0.20$, others 0.10, rate 6.0×10^{-5} ; (3) $[\text{Q}] = 0.30$, others 0.10, rate 2.7×10^{-4} ; (4) $[\text{R}] = 0.40$, others 0.10, rate 3.0×10^{-5} .

1. Deduce the order with respect to P, Q and R.
2. Write the rate equation and calculate k with units.
3. Predict the rate when $[\text{P}] = 0.25$, $[\text{Q}] = 0.15$ and $[\text{R}] = 0.05 \text{ mol/dm}^3$.

Problem 17 Which mechanism? (hard)

The reaction $2\text{ICl} + \text{H}_2 \rightarrow \text{I}_2 + 2\text{HCl}$ has rate $= k[\text{ICl}][\text{H}_2]$. Mechanism A: $\text{ICl} + \text{H}_2 \rightarrow \text{HI} + \text{HCl}$ (slow), then $\text{HI} + \text{ICl} \rightarrow \text{I}_2 + \text{HCl}$ (fast). Mechanism B: $2\text{ICl} \rightarrow \text{I}_2 + \text{Cl}_2$ (slow), then $\text{Cl}_2 + \text{H}_2 \rightarrow 2\text{HCl}$ (fast).

1. Show that mechanism A gives the overall equation.
2. Write the rate equation predicted by each mechanism.
3. State which mechanism fits the data and identify the intermediate in it.

Problem 18 Rate constant at a new temperature (hard)

A reaction has $E_a = 65.0 \text{ kJ/mol}$ and $k = 2.5 \times 10^{-4} \text{ s}^{-1}$ at 298 K.

1. Calculate $\ln(k_2/k_1)$ for 318 K (45 °C).
2. Calculate k at 318 K.
3. State how many times faster the reaction is.

Problem 19 Decomposition on a surface (hard)

A gas decomposes on a hot metal surface. $[\text{A}]$ is 0.100, 0.085, 0.070, 0.055 and 0.040 mol/dm^3 at 0, 100, 200, 300 and 400 s.

1. Deduce the order and explain.
2. Calculate k with units.
3. Calculate the first half-life from 0.100 mol/dm^3 and the half-life starting at 0.050 mol/dm^3 .

Problem 20 Spot the errors (hard)

Find and correct the error in each statement.

1. For $2\text{A} + \text{B} \rightarrow \text{C}$ the rate equation is $\text{rate} = k[\text{A}]^2[\text{B}]$.
2. k for a second order reaction has units s^{-1} .
3. A catalyst speeds up the reaction by increasing the temperature.
4. The rate-determining step is the fastest step.