

Orders, rate constants and activation energy

Chemistry grades 11-12 (A Level · IB · Class 11-12) · Test answers (mark scheme)

Model answers and mark schemes follow. Give credit for correct reasoning even if a later numerical slip occurs, and check the units of every rate constant.

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

Question 1 Units of k (2 marks)

(a) **Second order** overall.

(b) $\text{mol dm}^{-3} \text{s}^{-1} = k \times (\text{mol dm}^{-3})^2$, so k has units **$\text{dm}^3 \text{mol}^{-1} \text{s}^{-1}$** .

Marking: 1 mark per part.

Question 2 Initial rates (3 marks)

Tripling $[P]$ triples the rate: first order in P . Doubling $[Q]$ has no effect: zero order in Q . Rate = $k[P]$. $k = 3.0 \times 10^{-4} / 0.10 = \mathbf{3.0 \times 10^{-3} \text{s}^{-1}}$.

Marking: 1 for both orders; 1 for the rate equation; 1 for k with units.

Question 3 Mechanism (3 marks)

Rate = $k[\text{H}_2\text{O}_2][\text{I}^-]$. Overall: **$2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2$** . I^- is the catalyst (used in step 1, regenerated in step 2) and IO^- is the intermediate.

Marking: 1 for the rate equation; 1 for the overall equation; 1 for catalyst and intermediate.

Question 4 Arrhenius graph (3 marks)

Gradient = $(-7.2 - (-4.0)) / (0.00340 - 0.00300) = -3.2 / 0.00040 = -8000 \text{ K}$. $E_a = 8000 \times 8.314 = 66\,512 \text{ J/mol} = \mathbf{66.5 \text{ kJ/mol}}$.

Marking: 1 for the gradient; 1 for $E_a = -\text{gradient} \times R$; 1 for the value in kJ/mol.

Question 5 Half-life (2 marks)

$t_{1/2} = 0.693 / 2.31 \times 10^{-2} = \mathbf{30.0 \text{ min}}$.

Marking: 1 for the expression; 1 for the value and unit.

Question 6 Temperature and rate (3 marks)

At a higher temperature more particles have energy at least equal to the activation energy, and the fraction rises exponentially. A small increase in collision frequency also helps, but the larger fraction of successful collisions is the main reason the rate increases greatly.

Marking: 1 for more particles with $E \geq E_a$; 1 for a large (exponential) change in the fraction; 1 for more frequent collisions as a smaller effect.

Question 7 Catalysts (2 marks)

A catalyst provides an alternative pathway with a lower activation energy, so a larger fraction of collisions are successful. It is regenerated at the end of the mechanism, so it is not used up.

Marking: 1 for lower activation energy via an alternative route; 1 for regeneration.

Question 8 Changing two concentrations (2 marks)

Factor for A: $2^1 = 2$. Factor for B: $(\frac{1}{2})^2 = \frac{1}{4}$. Overall = $2 \times \frac{1}{4} = \frac{1}{2}$, so the rate halves.

Marking: 1 for the factors for A and B; 1 for the combined factor.