

Mechanisms, catalysts and activation energy

AP Chemistry · Test answers (mark scheme)

Model answers and a marking guide follow. Give credit for correct reasoning carried forward from an earlier mistake, and accept the rate law in any equivalent form, for example with the product of constants written as a single k .

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

Question 1 Elementary steps (2 marks)

- (a) **Bimolecular**.
(b) Rate = $k[\text{NO}_2]^2$.

Marking: 1 mark each.

Question 2 Testing a mechanism (3 marks)

- (a) $\text{NO}_2\text{Cl} + \text{NO}_2\text{Cl} + \text{Cl} \rightarrow \text{NO}_2 + \text{Cl} + \text{NO}_2 + \text{Cl}_2$; cancel Cl: **$2 \text{NO}_2\text{Cl} \rightarrow 2 \text{NO}_2 + \text{Cl}_2$** .
(b) The intermediate is **Cl**.
(c) Rate = $k[\text{NO}_2\text{Cl}]$ (slow step unimolecular).

Marking: 1 mark for each part.

Question 3 Energy profile (3 marks)

- (a) $95 - 20 = \mathbf{75 \text{ kJ}}$.
(b) $\Delta H = 55 - 20 = \mathbf{+35 \text{ kJ}}$, endothermic.
(c) $95 - 55 = \mathbf{40 \text{ kJ}}$.

Marking: 1 mark each.

Question 4 Role of a catalyst (2 marks)

A catalyst provides an alternative pathway with a **lower activation energy**, so a larger fraction of collisions are successful and the rate increases. It does **not change ΔH** .

Marking: 1 for lower E_a or alternative path with effect on rate; 1 for ΔH unchanged.

Question 5 Activation energy (3 marks)

$$E_a = R \ln(k_2/k_1)/(1/T_1 - 1/T_2) = 8.314 \times \ln 4.0/(1/350 - 1/370) = 8.314 \times 1.386/(1.544 \times 10^{-4}) = 7.46 \times 10^4 \text{ J/mol} = \mathbf{75 \text{ kJ/mol}}$$

Marking: 1 for $\ln 4.0$, 1 for the temperature term, 1 for the answer in kJ/mol.

Question 6 Fast equilibrium (3 marks)

(a) Rate = $k_2[\text{N}_2\text{O}_2][\text{O}_2]$; $K = [\text{N}_2\text{O}_2]/[\text{NO}]^2$, so rate = $k_2K[\text{NO}]^2[\text{O}_2] = \mathbf{k[\text{NO}]^2[\text{O}_2]}$.

(b) **Third order.**

Marking: 1 for rate of the slow step, 1 for substituting $[\text{N}_2\text{O}_2]$, 1 for the order.

Question 7 Catalyst or intermediate (2 marks)

Catalysts: **Br⁻** (and H⁺); intermediate: **HOBr**.

Marking: 1 for the catalyst, 1 for the intermediate.

Question 8 Temperature and collisions (2 marks)

At higher temperature the energy distribution shifts and widens, so a **larger fraction of collisions has energy of at least E_a** ; the number of successful collisions per second grows, and k increases.

Marking: 1 for the larger fraction above E_a ; 1 for linking it to more successful collisions and larger k .