ANSWER KEY & MARKING SCHEME · CBSE CLASS 12

Chemical Kinetics

Chemistry · Chapter 3 · Use this with the Board Paper · Companion to Quick Drill

HOW TO USE

Attempt the Board Paper first (closed-book, full time). Then come here. For 2-mark+ questions, compare your answer to the model. For 3-4 mark questions, also consult the **Topper Templates** below — these show the exact step-by-step structure that scores full marks per CBSE marking-scheme conventions.

MODEL ANSWERS · BOARD PAPER

Section A — Very Short Answer (1 mark each)

Q1. Define rate of a chemical reaction. [1 mark]

Ans: The change in concentration of a reactant or product per unit time. Rate = $-\Delta$[reactant]/Δt = $+\Delta$[product]/Δt.

Q2. Write the units of rate constant for a zero-order reaction. [1 mark]

Ans: mol L^{-1} s^{-1} (or mol L^{-1} min^{-1}).

Q3. What is the value of half-life of a first-order reaction in terms of rate constant? [1 mark]

Ans: $t_{½}$ = 0.693/k

Q4. State whether molecularity of a reaction can be zero. [1 mark]

Ans: No. Molecularity is the number of reactant species in an elementary step — it must be a positive integer (1, 2, or rarely 3).

Section B — Short Answer I (2 marks each)

Q5. Differentiate between order and molecularity of a reaction (any two differences). [2 marks]

Ans: (1) Order is experimentally determined from the rate law; molecularity is the count of reactant species in an elementary step. (2) Order can be zero, fractional, or negative; molecularity is always a positive integer (1, 2, or rarely 3). (3) Order is defined for both elementary and complex reactions; molecularity is defined only for elementary steps.

Q6. Derive the expression for half-life of a zero-order reaction. [2 marks]

Ans: For zero order: rate = –d[A]/dt = k. Integrating: $[A] = [A]_0 - kt$. At $t = t_{½}$, $[A] = [A]_0/2 \Rightarrow [A]_0/2 = [A]_0 - k \cdot t_{½} \Rightarrow t_{½} = [A]_0/(2k)$. $t_{½}$ depends on $[A]_0$.

Q7. Draw the energy-profile diagram showing the effect of a catalyst. Label Ea (uncatalysed), Ea (catalysed), and ΔH. [2 marks]

Ans: Two curves on a 'PE vs reaction-coordinate' axis. Reactant level at left, product level at right (below reactant for exothermic). Uncatalysed curve: high peak labelled Ea; catalysed curve (dashed): lower peak labelled Ea(cat). ΔH = difference between reactant and product levels — same for both curves. Catalyst lowers Ea, NOT ΔH.

Q8. Define rate constant. State two factors on which it depends. [2 marks]

Ans: Rate constant (k) is the proportionality constant in the rate law rate = k[A]^x[B]^y; it equals the rate when all reactant concentrations are unity. It depends on (i) temperature (via Arrhenius equation) and (ii) presence of a catalyst. It does NOT depend on concentration.

Section C — Short Answer II (3 marks each)

Q9. A first-order reaction has a rate constant k = 0.0231 min^{-1}. Calculate (i) the half-life and (ii) the time required for 75% completion of the reaction. [3 marks]

Ans: (i) $t_{½}$ = 0.693/k = 0.693/0.0231 = 30 min. (ii) 75% completed $\Rightarrow$ [A] = 0.25$[A]_0$; $[A]_0/[A] = 4$. $t = (2.303/k) \cdot \log 4 = (2.303/0.0231) \times 0.602 = 99.7 \times 0.602 = 60$ min. Notice 60 min = 2 × $t_{½}$ — consistent with 75% being two half-lives' worth.

Q10. The rate of a reaction quadruples when the temperature changes from 293 K to 313 K. Calculate the activation energy. ($R = 8.314$ J K^{-1} mol^{-1}; log 4 = 0.6021) [3 marks]

Ans: $\ln(k_2/k_1) = (Ea/R)(T_2 - T_1)/(T_1 \cdot T_2)$. $\ln 4 = 2.303 \times 0.6021 = 1.386$. $T_1 \cdot T_2 = 293 \times 313 = 91{,}709$. $(T_2 - T_1) = 20$. $1.386 = (Ea/8.314)(20/91709) \Rightarrow Ea = 1.386 \times 8.314 \times 91709/20 = 1.386 \times 8.314 \times 4585 = 52{,}847$ J/mol ≈ 52.8 kJ/mol.

Q11. What is meant by pseudo-first-order reaction? Give one example and explain. [3 marks]

Ans: A pseudo-first-order reaction is a bimolecular (or higher) reaction that APPEARS first-order because one reactant is present in very large excess and its concentration remains essentially constant during the reaction. Example: acid-catalysed hydrolysis of methyl acetate: $CH_3COOCH_3 + H_2O \rightarrow CH_3COOH + CH_3OH$. Although the rate law is rate = k[ester][H_2O], since [H_2O] is in huge excess (~55 M vs ester at ~0.1 M), [H_2O] hardly changes. We define $k' = k[H_2O]$, giving rate = k′[ester] — apparent first-order kinetics. True molecularity is 2.

Q12. Derive the integrated rate equation for a first-order reaction A → product, and obtain expressions for (i) the rate constant k and (ii) the half-life $t_{½}$. [3 marks]

Ans: For first order: rate = $-d[A]/dt = k[A]$. Separating variables: $-d[A]/[A] = k \cdot dt$. Integrating from $[A]_0$ at t = 0 to [A] at time t: $-\ln[A] + \ln[A]_0 = kt \Rightarrow \ln([A]_0/[A]) = kt$. Therefore (i) $k = (1/t) \cdot \ln([A]_0/[A]) = (2.303/t) \cdot \log([A]_0/[A])$. (ii) For half-life, $[A] = [A]_0/2$: $kt_{½} = \ln 2 = 0.693 \Rightarrow t_{½} = 0.693/k$. $t_{½}$ is independent of $[A]_0$ — the defining feature of first-order kinetics.

Section D — Long Answer (6 marks)

Q13. (a) Explain the terms 'order' and 'molecularity' of a reaction with one example each. (3 marks) (b) The decomposition of N_2O_5 in CCl_4 follows first-order kinetics. After 30 min from the start, the concentration of N_2O_5 is found to be 0.30 mol/L; after 60 min, it is 0.15 mol/L. Calculate the rate constant. (3 marks) [6 marks]

Ans: (a) Order: sum of powers in the experimentally determined rate law; can be 0, fractional, or integer; example — decomposition of H_2O_2 on Pt surface is zero order. Molecularity: number of reactant species in an elementary step; always 1, 2, or rarely 3; example — $2HI \rightarrow H_2 + I_2$ is bimolecular (molecularity = 2). They coincide for elementary reactions only. (b) Concentration halves from 0.30 to 0.15 between t = 30 min and t = 60 min — that 30-min span is one half-life of the substance, so $t_{½}$ = 30 min. For first order: $k = 0.693/t_{½} = 0.693/30 = 0.0231$ $min^{-1} \approx 2.31 \times 10^{-2}$ min^{-1}. (Verification: at t = 60, $[A] = [A]_0 \cdot e^{(-k \cdot 60)} = [A]_0 \cdot e^{(-1.386)} = [A]_0 \cdot 0.25$, matching halving from 0.30 to 0.15 since the 30-min point IS $[A]_0$ for this interval.)

★ TOPPER ANSWER TEMPLATES

5 TEMPLATES · MEMORISE THE FORMAT

★ TOPPER TEMPLATE — Pseudo-first-order numerical (k and time)

A high-yield 3-mark numerical in CBSE Class 12 Chemical Kinetics.

Step 1 [1 mark]	**Find k from $t_{½}$**	50% decomposed ⇒ t = $t_{½}$ = 24 min. Apply $t_{½} = 0.693/k \Rightarrow k = 0.693/24 = 2.888 \times 10^{-2}$ min^{-1}.
Step 2 [1 mark]	**Set up first-order time eq**	For 90% decomposition $[A] = 0.10[A]_0$. Use $t = (2.303/k) \log([A]_0/[A]) = (2.303/0.02888) \log(100/10)$.
Step 3 [1 mark]	**Compute & state units**	$t = 79.74 \times \log(10) = 79.74 \times 1 \approx 79.7$ min.

COMMON LOSS OF MARKS:

- Writing t = 0.693/k for 90% (wrong — that formula is half-life only).
- Forgetting the 2.303 conversion between ln and log.
- Reporting answer without units (min).

★ TOPPER TEMPLATE — Arrhenius activation-energy calculation

A regular 3-mark numerical in CBSE Class 12 Chemical Kinetics.

Step 1 [1 mark]	**Write two-temperature Arrhenius**	$\ln(k_2/k_1) = (E_a/R)\cdot(T_2-T_1)/(T_1\cdot T_2)$.
Step 2 [1 mark]	**Substitute values**	$k_2/k_1 = 2 \Rightarrow \ln 2 = 0.693$; $R = 8.314$ J K^{-1} mol^{-1}; $T_1 = 298$ K, $T_2 = 308$ K.
Step 3 [1 mark]	**Compute E_a with units**	$E_a = (0.693 \times 8.314 \times 298 \times 308)/10 \approx 52\,885$ J ≈ 52.9 kJ mol^{-1}.

COMMON LOSS OF MARKS:

- Inverting (T2 – T1) sign and getting negative Ea.
- Using R = 0.0821 (gas-law R) instead of 8.314 J/K/mol.
- Reporting Ea in J without converting to kJ when question asks kJ.

★ TOPPER TEMPLATE — Order vs molecularity comparison

A recurring 3-mark conceptual question in CBSE Class 12 Chemical Kinetics.

Step 1 [1 mark]	**Differences 1 & 2**	Order is found experimentally from the rate law; molecularity is theoretical (count of species in an elementary step). Order may be 0, fractional, negative or integer; molecularity is a positive integer (1, 2, rarely 3).
Step 2 [1 mark]	**Difference 3**	Order is defined for both elementary and complex reactions; molecularity is defined ONLY for elementary steps.
Step 3 [1 mark]	**One example each**	Order: decomposition of H_2O_2 is first order. Molecularity: $2HI \rightarrow H_2 + I_2$ is bimolecular (molecularity = 2).

COMMON LOSS OF MARKS:

- Saying 'molecularity = sum of stoichiometric coefficients' (wrong for non-elementary).
- Not giving an example (1 mark lost).
- Confusing 'rate constant' with 'order' in the table.

★ TOPPER TEMPLATE — Catalysed vs uncatalysed potential-energy graph

A common 2-mark graph question in CBSE Class 12 Chemical Kinetics.

Step 1 [1 mark]	**Correct curve shape**	Plot potential energy (y) vs reaction coordinate (x): reactant level on the left, product level on the right; a solid high-peak curve (uncatalysed) and a dashed lower-peak curve (catalysed).
Step 2 [1 mark]	**Label E_a, E_a(cat), ΔH**	Mark E_a (reactant → high peak), E_a(cat) (reactant → low peak) and ΔH (reactant – product level); the catalyst lowers E_a but does not change ΔH.

COMMON LOSS OF MARKS:

- Drawing a single curve (no comparison).
- Showing catalyst changing ΔH (it doesn't).
- Missing the 'reaction coordinate' label.

★ TOPPER TEMPLATE — Zero-order half-life derivation

A standard 2-mark derivation in CBSE Class 12 Chemical Kinetics.

Step 1 [1 mark]	**Integrated rate law**	For zero order, rate = $-d[A]/dt = k$. Integrating gives $[A] = [A]_0 - kt$.
Step 2 [1 mark]	**Derive $t_{½}$ & state dependence**	At $t = t_{½}$, $[A] = [A]_0/2 \Rightarrow [A]_0/2 = [A]_0 - k\cdot t_{½} \Rightarrow t_{½} = [A]_0/(2k)$; hence $t_{½}$ is directly proportional to initial concentration.

COMMON LOSS OF MARKS:

- Skipping the integration step.
- Confusing with first-order $t_{½} = 0.693/k$.
- Not stating the dependence in the conclusion.

MARKING SCHEME — GENERAL NOTES

- Award full marks for any correct alternative method, including dimensional analysis or graphical reasoning.
- For numerical problems, the final answer carries 50% weight; the working method carries 50%. Award partial marks for correct method even if the final value is wrong by arithmetic.
- Deduct 0.5 mark if units are missing or incorrect on a final numerical answer.
- For derivations, the integration step is worth 50% of the question marks; the substitution and final form are worth the other 50%.
- Energy-profile diagrams must show two curves to receive full marks; a single curve loses 50%.
- Accept either $\ln(k_2/k_1)$ form or two-temperature Arrhenius equation for Ea calculations. Do not penalise method choice.
- If R = 0.0821 L atm K^{-1} mol^{-1} is used instead of 8.314 J K^{-1} mol^{-1} in an energy-units question, deduct 1 mark.