Zero Order Reactions

1. **[JEE Main 2018]** A zero-order reaction takes 20 minutes for 25% completion. Calculate the time required for 75% completion. *Solution:*
    - For zero order: $[A]t = [A]_0 - kt$
    - 25% completion means $[A]t = 0.75[A]_0$
    - If $t_1 = 20$ min, then: $0.75[A]_0 = [A]_0 - kt_1$
    - $k = 0.0125[A]_0$/min
    - For 75% completion: $0.25[A]_0 = [A]_0 - kt_2$
    - $t_2 = 60$ minutes
2. **[JEE Main 2015]** The half-life of a zero-order reaction is 50 min at $[A]_0 = 0.1$ M. Calculate the rate constant. *Solution:*
    - For zero order: $t_{1/2} = [A]_0/2k$
    - $50 = 0.1/(2k)$
    - $k = 0.001$ M/min

First Order Reactions

3. **[JEE Main 2019]** The rate constant for a first-order reaction is 1.54×10^{-3} s^{-1}. Calculate its half-life. *Solution:*
    - $t_{1/2} = 0.693/k$
    - $t_{1/2} = 0.693/(1.54 \times 10^{-3})$
    - $t_{1/2} = 450$ s
4. **[JEE Main 2016]** A first-order reaction takes 40 min for 30% decomposition. Calculate the time for 60% decomposition. *Solution:*
    - Using: $\ln([A]_0/[A]t) = kt$
    - For 30%: $\ln(100/70) = k \times 40$
    - $k = 0.0089$ min^{-1}
    - For 60%: $\ln(100/40) = 0.0089 \times t$
    - $t = 102.5$ min

Temperature Dependence

5. **[JEE Main 2017]** The activation energy of a reaction is 75.2 kJ/mol. If the temperature increases from 27°C to 37°C, calculate the ratio of rate constants (k_2/k_1). *Solution:*
    - Using: $\ln(k_2/k_1) = -(Ea/R)(1/T_2 - 1/T_1)$
    - $T_1 = 300$K, $T_2 = 310$K
    - $k_2/k_1 = 2.03$
6. **[JEE Main 2020]** Rate constant doubles when temperature changes from 300K to 310K. Calculate activation energy. *Solution:*
    - $\ln(2) = (Ea/R)(1/300 - 1/310)$
    - $Ea = 52.8$ kJ/mol

Complex Reactions

7. **[JEE Main 2014]** For parallel reactions A → B ($k_1 = 0.3\ s^{-1}$) and A → C ($k_2 = 0.1\ s^{-1}$), calculate the ratio of products [B]/[C] after completion. *Solution:*
    - Rate of B formation = $k_1[A]$
    - Rate of C formation = $k_2[A]$
    - $[B]/[C] = k_1/k_2 = 3$
8. **[JEE Main 2013]** In consecutive reactions A → B → C, if $k_1 = 0.2\ s^{-1}$ and $k_2 = 0.1\ s^{-1}$, calculate maximum concentration of B relative to initial [A]. *Solution:*
    - $[B]max/[A]_0 = (k_1/(k_2-k_1))(e^{(-k_1t)} - e^{(-k_2t)})$
    - Maximum occurs at $t = \ln(k_2/k_1)/(k_2-k_1)$
    - $[B]max/[A]_0 = 0.37$

Rate Laws and Order

9. **[JEE Main 2021]** Initial rates for reaction 2A + B → C at different concentrations: $[A]_0$ (M) | $[B]_0$ (M) | Initial Rate (M/s) 0.1 | 0.1 | 0.001 0.2 | 0.1 | 0.004 0.1 | 0.2 | 0.002 Find the order with respect to A and B. *Solution:*
    - Comparing rows 1&2: Rate $\propto [A]^2$
    - Comparing rows 1&3: Rate $\propto [B]$
    - Order w.r.t A = 2, B = 1
    - Total order = 3
10. **[JEE Main 2012]** For reaction A + B → C, when [A] doubles keeping [B] constant, rate quadruples. When [B] doubles keeping [A] constant, rate doubles. Find the rate law. *Solution:*
    - Rate $\propto [A]^2$ from first data
    - Rate $\propto [B]$ from second data
    - Rate = $k[A]^2[B]$

Half-Life Problems

11. **[JEE Main 2016]** A second-order reaction has $t_{1/2} = 100s$ when $[A]_0 = 0.1M$. Calculate $t_{1/2}$ when $[A]_0 = 0.2M$. *Solution:*
    - For second order: $t_{1/2} \propto 1/[A]_0$
    - New $t_{1/2} = 50s$
12. **[JEE Main 2019]** If three successive half-lives of a first-order reaction are 10, 10, and 10 minutes respectively, what fraction of reactant remains? *Solution:*
    - After each $t_{1/2}$, concentration halves
    - After 3 half-lives: $[A]/[A]_0 = (1/2)^3$
    - Remaining fraction = 0.125

Pseudo First Order

13. **[JEE Main 2017]** Hydrolysis of ester with excess water follows pseudo first-order kinetics. If $k' = 2.0 \times 10^{-2}\ s^{-1}$, calculate t_{99}% (time for 99% completion). *Solution:*

- Using $\ln([A]_0/[A]t) = k't$
- $\ln(100/1) = 0.02t$
- $t = 230s$

Catalyst Effects

14. **[JEE Main 2015]** A reaction has Ea = 100 kJ/mol. A catalyst reduces it to 60 kJ/mol. Calculate ratio of rate constants at 300K. *Solution:*
    - $k_2/k_1 = e^{[(Ea_1-Ea_2)/RT]}$
    - $k_2/k_1 = e^{[40000/(8.314\times300)]}$
    - $k_2/k_1 = 3.2 \times 10^7$

Integrated Rate Laws

15. **[JEE Main 2020]** Plot of 1/[A] vs time is linear with slope 0.5 $M^{-1}s^{-1}$. If $[A]_0 = 0.1M$, calculate time for 80% completion. *Solution:*
    - Second order reaction
    - $1/[A]t = 1/[A]_0 + kt$
    - $1/(0.2\times0.1) = 1/0.1 + 0.5t$
    - $t = 32s$

Mixed Concepts

16. **[JEE Main 2014]** A first-order reaction at 300K has $k = 2.0 \times 10^{-2}\ s^{-1}$. Calculate Ea if k doubles at 310K. *Solution:*
    - Using $\ln(k_2/k_1) = -(Ea/R)(1/T_2 - 1/T_1)$
    - $\ln(2) = (Ea/8.314)(1/300 - 1/310)$
    - Ea = 52.8 kJ/mol
17. **[JEE Main 2018]** For reaction $2NO + O_2 \rightarrow 2NO_2$, initial rates at different concentrations: [NO] (M) | $[O_2]$ (M) | Rate (M/s) 0.1 | 0.1 | 0.001 0.1 | 0.2 | 0.002 0.2 | 0.1 | 0.004 Find rate law and k. *Solution:*
    - Rate $\propto [NO]^2$ from rows 1&3
    - Rate $\propto [O_2]$ from rows 1&2
    - Rate $= k[NO]^2[O_2]$
    - $k = 1.0\ M^{-2}s^{-1}$
18. **[JEE Main 2016]** A reaction has $t_{90}\%$ = 230s at 300K and 115s at 310K. Calculate Ea. *Solution:*
    - $t_{90}\% \propto 1/k$
    - $k_2/k_1 = 230/115 = 2$
    - Using Arrhenius equation
    - Ea = 52.8 kJ/mol
19. **[JEE Main 2019]** For parallel decomposition A → B and A → C, if 60% of A forms B and 40% forms C, calculate k_1/k_2. *Solution:*
    - $[B]/[C] = k_1/k_2$
    - $60/40 = k_1/k_2$
    - $k_1/k_2 = 1.5$

20. **[JEE Main 2017]** A reaction follows first order kinetics. Calculate concentration of reactant at time equal to mean life (τ). *Solution:*
    - Mean life $\tau = 1/k$
    - $[A] = [A]_0 e^{(-t/\tau)}$
    - At $t = \tau$, $[A] = [A]_0/e$
    - $[A] = 0.368[A]_0$