GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER 6 – OLD PAPER – S22 TO S26 – QUESTION BANK

Subject Name & Code: Chemical Reactions Engineering I - 3160506

Chapter 1 – Overview of chemical reaction engineering, Classification of reactions, Variables affecting rate, Definition of reaction rate, single and multiple reactions, Elementary and non-elementary reactions, molecularity and order of reaction, extent of reactions, conversion, Selectivity, Reaction rate fundamentals - elementary reaction sequences, steady state approximation and rate limiting step theory

Repeated Questions:

1. Classification of Reactions and Variables Affecting Rate (Theory):

- **Q.** Describe/Discuss the variables affecting the rate of reactions. **(WINTER 2022, 4 Marks; SUMMER 2023, 3 Marks; SUMMER 2025, 3 Marks)**
- **Q.** Discuss the variables affecting rate of homogeneous and heterogeneous reactions with suitable example. **(SUMMER 2024, 7 Marks)**
- **Q.** Give detail classification of reactions with example. / Classify reactions and give suitable industrial example of such reaction. / Classify chemical reactions on the basis of (a) number of phases involved and (b) heat or reaction with suitable example. **(WINTER 2023, 3 Marks; SUMMER 2025, 7 Marks; WINTER 2025, 3 Marks)**
- **Q.** Explain homogeneous and heterogeneous catalytic reaction with suitable example. **(SUMMER 2023, 4 Marks; WINTER 2024, 3 Marks)**
- **Q.** Define rate of reaction considering unit volume, mass and surface of solid in fluid solid system. **(SUMMER 2025, 4 Marks)**

2. Elementary Reactions, Molecularity and Order (Theory):

- **Q.** Define molecularity, order of reaction and rate constant 'k'. State the general unit for rate constant 'k'. / Define rate constant. Derive the unit of rate constant. / Develop an expression that facilitates calculation of units of rate constant for any order. Give the unit of rate constant for first, second and third order reaction. **(SUMMER 2022, 4 Marks; WINTER 2022, 3 Marks; SUMMER 2023, 4 Marks; SUMMER 2025, 3 Marks; SUMMER 2026, 7 Marks OR)**
- **Q.** Define Elementary and Non-elementary reactions with suitable example. / Explain elementary reaction with example. **(SUMMER 2022, 3 Marks; SUMMER 2024, 4 Marks; SUMMER 2026, 3 Marks)**
- **Q.** Justify - Molecularity of reaction can never be more than three. **(WINTER 2023, 3 Marks - total for Q1A)**
- **Q.** Why can the order of reaction be zero, but the molecularity of a reaction cannot be? **(WINTER 2023, 3 Marks - total for Q1A; SUMMER 2024, 3 Marks)**
- **Q.** Define zero order reaction with suitable example. **(WINTER 2022, 3 Marks OR)**
- **Q.** $N_2 + 3H_2 \longrightarrow 2NH_3$. With suitable justification classify this reaction as elementary or non elementary reaction. **(WINTER 2025, 3 Marks)**

3. Reaction Mechanism, Intermediates and Steady State Approximation:

- **Q.** Define an intermediate. What are the different types of intermediates that are suggested by the chemistry of the materials? **(WINTER 2023, 3 Marks - total for Q1A)**

- **Q.** Explain that non-elementary reactions are taking place in multiple steps. / Discuss the conditions required for steady state approximation. / Describe the mechanism of non-elementary reaction. **(SUMMER 2023, 4 Marks OR; SUMMER 2024, 3 Marks; WINTER 2024, 3 Marks)**
- **Q.** Explain the method for searching the mechanism of chemical reaction. **(WINTER 2023, 3 Marks OR)**
- **Q.** The reaction between nitric oxide and oxygen given below $2NO + O_2 \rightarrow 2NO_2$ follows the rate law $-d[O_2]/dt = k[NO]^2[O_2]$. Suggest a reaction mechanism which is consistent with this rate law. **(WINTER 2023, 7 Marks)**
- **Q.** Derive rate of reaction for homogeneous catalytic reaction. **(WINTER 2024, 3 Marks)**

4. Numerical Problems:

- **Q.** A human being (75 kg) consumes about 6000 kJ of food per day. Assume that the food is all glucose and that the overall reaction is $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$, $-\Delta H_r = 2816$ kJ. Find man's metabolic rate (the rate of living, loving, and laughing) in terms of moles of oxygen used per m^3 of person per second. (Assume density of man = 1000 kg/m^3) **(WINTER 2023, 7 Marks)**

Other Important Questions:

1. Reaction Rate and Rate Constant (Numerical):

- **Q.** Phosphine decomposes when heated according to the following reaction: $4PH_3(g) \rightarrow P_4(g) + 6H_2(g)$. At a given instant, the rate at which phosphine decomposes is 2.4×10^{-3} mol/(l.s). (a) Express the rate in three different ways, using differential notation and show the relationship between them. (b) What is the rate of formation of (i) P_4 and (ii) H_2? **(SUMMER 2024, 7 Marks)**
- **Q.** A certain reaction has a rate given by $-r_A = 0.005\ C_A^2$, (mol/cm^3.min). If the concentration is expressed in mol/l and time in hours, what would be the value and units of rate constant? **(SUMMER 2024, 7 Marks OR)**
- **Q.** $dp_A/dt = 3.66\ p_A^3$ atm/hr. (a) What are the units of the rate constant? (b) What is the value of the rate constant for this reaction if the rate equation is expressed as: $-r_A = -(1/V)\ dN_A/dt = kC_A^3$ mol/m^3·s **(SUMMER 2026, 7 Marks OR)**

Chapter 2 – Kinetics: Constant volume and variable volume batch, CSTR and PFR reactor data, data collection & plotting, linearization of rate equations. Analysis of total pressure data obtained from a constant-volume batch reactor, Integral and differential methods of analysis of data, Autocatalytic reactions, Reversible reactions, and Bio-chemical reactions.

Repeated Questions:

1. Methods of Analysis of Kinetic Data (Theory):

- **Q.** Differentiate/Explain integral and differential method of analysis. / Discuss in detail about Integral method and Half life Method. / Discuss in detail about Integral method of analysis of batch reactor kinetic data. **(WINTER 2022, 4 Marks; SUMMER 2023, 7 Marks; WINTER 2023, 3 Marks OR; SUMMER 2024, 4 Marks; SUMMER 2025, 4 Marks; SUMMER 2026, 3 Marks; SUMMER 2026, 3 Marks OR)**
- **Q.** Analysis of total pressure data obtained in a constant-volume system and establish the relation used to calculate the partial pressure of gaseous component in reaction mixture. / Explain theory - Analysis of total pressure data obtained in constant-volume system. **(WINTER 2022, 7 Marks; WINTER 2023, 7 Marks OR)**
- **Q.** Write a short note on 'Variable volume batch reactor'. / What do you mean by constant volume and variable volume system? **(SUMMER 2023, 3 Marks; SUMMER 2024, 4 Marks)**
- **Q.** Explain with example autocatalytic reaction. / Discuss autocatalytic reaction with conversion-time and rate-concentration curves. **(WINTER 2022, 4 Marks OR; SUMMER 2023, 7 Marks OR; SUMMER 2024, 3 Marks OR; SUMMER 2025, 4 Marks OR; SUMMER 2026, 4 Marks OR)**
- **Q.** What is bio-chemical reaction? Explain with example. / Describe in detail biochemical reactions. **(SUMMER 2022, 3 Marks; SUMMER 2023, 4 Marks)**

2. Derivations:

- **Q.** Derive the equation for half-life using overall order of irreversible reaction. / Define half-life time and write the formula to calculate $t_{1/2}$. **(SUMMER 2023, 3 Marks OR; WINTER 2023, 4 Marks; SUMMER 2024, 7 Marks OR; SUMMER 2025, 7 Marks)**
- **Q.** Develop an expression that facilitates calculation of units of rate constant for any order. Give the unit of rate constant for first, second and third order reaction. **(SUMMER 2022, 4 Marks; SUMMER 2026, 7 Marks OR)**
- **Q.** Show that the time required for 99% conversion is double the time required for 90% conversion for first order irreversible, unimolecular reaction. **(SUMMER 2022, 7 Marks)**
- **Q.** Show that $\ln[(M - X_A)/(M(1 - X_A))] = C_{A0}(M - 1)kt$, $M \neq 1$ for second order irreversible bimolecular type reaction A + B ⟶ Products with different concentration of reactants A and B. **(WINTER 2022, 7 Marks OR)**

3. Reversible Reactions (Numerical):

- **Q.** The first-order reversible liquid phase reaction A ⇌ R, C_{A0} = 0.5 mol/lit, C_{R0} = 0. After 8 minutes, conversion of A is 33.3% while equilibrium conversion is 66.7%. Find the rate equation for this reaction. **(SUMMER 2023, 7 Marks OR; WINTER 2025, 7 Marks; SUMMER 2026, 7 Marks)**

Other Important Questions:

1. Theory and Derivations:

- **Q.** Give brief about shifting order reaction. **(SUMMER 2025, 4 Marks)**
- **Q.** Derive equation for a unimolecular type first order reaction for constant volume batch reactor using integral method. **(SUMMER 2025, 3 Marks)**
- **Q.** Derive the rate expression for Irreversible Unimolecular-Type First-Order Reactions. **(SUMMER 2026, 4 Marks)**

- **Q.** Derive rate expression for 2nd order reaction, A + B ⟶ R + S, where $C_{A0} = C_{B0}$ **(WINTER 2024, 4 Marks)**
- **Q.** It is stated that the half-life method for finding reaction order can be used to any fractional-life data. Do this, defining $t_{1/m}$ as the time required for the concentration of the reactant to drop to $1/m^{th}$ of its original/initial value. **(WINTER 2023, 4 Marks)**

2. Order of Reaction and Activation Energy (Numerical):

- **Q.** On doubling the concentration of reactants, the rate of reaction increases four times. Find the order of reaction. **(WINTER 2023, 3 Marks)**
- **Q.** On doubling the concentration of reactant, the rate of reaction triples. Find the reaction order. **(SUMMER 2026, 3 Marks)**
- **Q.** At 1100 K n-nonane thermally cracks (breaks down into smaller molecules) 20 times as rapidly as at 1000 K. Find the activation energy for this decomposition. **(SUMMER 2023, 7 Marks)**

3. Rate Equation from Batch and Mixed Flow Data (Numerical):

- **Q.** In a homogeneous isothermal liquid polymerization, 20% of the monomer disappears in 34 minutes for initial monomer concentration of 0.04 and also for 0.8 mol/liter. What rate equation represents the disappearance of the monomer? **(SUMMER 2023, 7 Marks)**
- **Q.** For the decomposition A → R, C_{A0} = 1 mol/liter, in a batch reactor conversion is 75% after 1 hour, and is just complete after 2 hours. Find a rate equation to represent this kinetics. **(SUMMER 2025, 7 Marks OR)**
- **Q.** Pure gaseous A at about 5 atm and 50 °C (150 mmol/liter) is fed into a 2 liter mixed flow reactor at various flow rates. There it decomposes, and the exit concentration of A is measured for each flow rate. From the following data find a rate equation to represent the kinetics of the decomposition of A. Assume that reactant A alone affects the rate. [Diagram required – refer to the original question paper] **(WINTER 2024, 7 Marks)**
- **Q.** Pure gaseous A at about 3 atm and 30 °C (120 mmol/liter) is fed into a 1 liter mixed flow reactor at various flow rates. There it decomposes, and the exit concentration of A is measured for each flow rate. From the following data find a rate equation to represent the kinetics of the decomposition of A. Assume that reactant A alone affects the rate. [Diagram required – refer to the original question paper] **(WINTER 2025, 7 Marks OR)**
- **Q.** For the stoichiometry A + B ⟶ (products), find the reaction orders with respect to A and B. [Diagram required – refer to the original question paper] **(WINTER 2025, 4 Marks)**

Chapter 3 – Homogeneous Single Reactions: Performance equations for ideal batch, Plug flow, Back-mix flow and semi batch reactors for isothermal condition, Size comparison of single reactors, Multiple-reactor systems, Recycle reactor, Optimum recycle operations.

Repeated Questions:

1. Performance Equations of Ideal Reactors (Derivations):

- **Q.** Derive the design/performance equation for steady state plug flow reactor. / Derive performance equation plug flow reactor. **(SUMMER 2023, 4 Marks; SUMMER 2025, 7 Marks; SUMMER 2026, 4 Marks OR)**
- **Q.** Derive the design/performance equation for steady state mixed flow reactor. / Derive performance equation for a CSTR. / Derive the performance equation for Mixed flow reactor. **(WINTER 2022, 7 Marks; SUMMER 2023, 4 Marks OR; SUMMER 2026, 4 Marks)**
- **Q.** Derive performance equation for a ideal batch reactor. / Derive performance equation for steady state ideal batch reactor. **(SUMMER 2024, 3 Marks; SUMMER 2025, 7 Marks)**
- **Q.** Derive performance equation for steady-state mixed flow reactor and discuss fractional conversion in terms of Damkohler number. **(WINTER 2023, 7 Marks OR)**
- **Q.** Derive equation in terms of concentration and conversion for zero order reaction. **(SUMMER 2023, 7 Marks)**

2. Definitions, Comparison and Selection of Reactors (Theory):

- **Q.** Define space time, space velocity & mean residence time. / Define: Space time, Space velocity, Holding time, Mean residence time. **(WINTER 2022, 3 Marks; WINTER 2023, 4 Marks OR; SUMMER 2024, 3 Marks; SUMMER 2026, 4 Marks)**
- **Q.** Explain-advantages, disadvantages and applications of batch reactors and continuous reactors. / Define and write about the advantages and disadvantages of Ideal batch reactor and also give industrial application of the same. / Discuss merits and demerits of batch and continuous modes of reactor operation. **(SUMMER 2022, 7 Marks; WINTER 2023, 4 Marks; SUMMER 2024, 3 Marks OR)**
- **Q.** Performance of PFR is better than CSTR for all positive order reactions. Justify above statement with suitable arguments and schematic diagram. [Diagram required – refer to the original question paper] **(WINTER 2025, 7 Marks)**
- **Q.** Discuss selection criteria for CSTR. **(SUMMER 2026, 3 Marks)**

3. Recycle Reactor:

- **Q.** What is recycle reactor? Write its uses. / Write a short note on Recycle reactor. / Explain recycle ratio and the performance equation of recycle plug flow reactors. **(SUMMER 2023, 3 Marks OR; SUMMER 2024, 4 Marks OR; SUMMER 2025, 3 Marks OR; SUMMER 2026, 3 Marks OR)**
- **Q.** Derive the design/performance equation for recycle reactor. / Derive performance equation for PFR with recycle. / Derive performance equation of Recycle reactor and discuss its graphical representation for constant and variable density. **(SUMMER 2022, 7 Marks; SUMMER 2023, 7 Marks; WINTER 2023, 7 Marks OR; WINTER 2024, 7 Marks)**

4. Multiple-Reactor Systems and Reactors in Series:

- **Q.** What is multiple-reactor systems? Explain its importance. **(SUMMER 2023, 3 Marks)**
- **Q.** Prove that N number of plug flow reactor connected in series and its total volume V gives the same conversion as a single plug flow reactor of volume V. / Show that performance of multiple PFR in series is equal to performance of single PFR having total volume of single PFR and multiple PFR equal and volumetric flow rate remains same for both cases. **(WINTER 2023, 7 Marks; SUMMER 2024, 4 Marks; WINTER 2024, 7 Marks)**

- **Q.** Explain Plug Flow Reactors in Series and in Parallel with equation. **(WINTER 2022, 4 Marks)**
- **Q.** Discuss equal sized mixed flow reactors in series. / Discuss the working of equal size CSTR in series. / Write short note on Multiple CSTRs in series. / Derive the performance equation for equal size CSTR's arranged in series. **(SUMMER 2022, 3 Marks OR; SUMMER 2024, 4 Marks OR; WINTER 2024, 4 Marks OR; WINTER 2025, 7 Marks OR)**
- **Q.** Explain the procedure to determine the best system for a given conversion when two CSTR of different sizes are connected in series. **(SUMMER 2022, 4 Marks; SUMMER 2026, 4 Marks)**
- **Q.** Discuss method of maximization of rectangles applied to find the optimum intermediate conversion and optimum sizes of two mixed flow reactors in series. **(WINTER 2022, 4 Marks)**
- **Q.** Equal sized mixed flow reactors in series. / For two equal sized CSTR in series, suggest procedure to be followed to find optimum intermediate conversion to have minimum volume of both reactors. **(WINTER 2022, 3 Marks; WINTER 2025, 4 Marks)**
- **Q.** Criteria for best arrangement of a set of ideal reactors. **(SUMMER 2022, 4 Marks OR)**
- **Q.** For multiple reactor, justify with suitable diagram that for all positive order reaction, PFR + small CSTR + large CSTR is best choice than any other combinations. / Why a larger CSTR as first reactor in three reactor sequence choice is worst selection for an arrangements of sequence of one PFR and two different size CSTRs in series for 2^{nd} order reaction. **(WINTER 2024, 7 Marks OR; WINTER 2025, 4 Marks OR)**

5. Numerical Problems:

- **Q.** The isothermal batch reactor, the conversion of a liquid reactant A achieved in 13 min is 70%. Find the space time and space velocity necessary to effect this conversion in a plug flow reactor and in a mixed flow reactor. Consider first order kinetics. **(SUMMER 2024, 7 Marks)**
- **Q.** Given a gaseous feed, $C_{A0} = 100$, $C_{B0} = 200$, $A + B \longrightarrow R + S$, $X_A = 0.9$. Find X_B, C_A, C_B. **(WINTER 2024, 3 Marks OR; WINTER 2025, 3 Marks - XA = 0.8 instead of 0.9)**
- **Q.** Aqueous feed of A and B (400 liter/min, 100 mmol A/liter, 200 mmol B/liter) is to be converted to product in a plug flow reactor. The kinetics of the reaction is represented by $A + B \rightarrow R$, $-r_A = 200\ C_A C_B$ mol/lit.min. Find the volume of reactor needed for 99.9% conversion of A to product. **(SUMMER 2023, 7 Marks; SUMMER 2026, 7 Marks)**

Other Important Questions:

1. Reactor Sizing and Design (Theory):

- **Q.** State the points to be considered to find the size of reactor required for given duty and for a given temperature progression. **(WINTER 2022, 3 Marks)**

2. Plug Flow and Mixed Flow Reactors (Numerical):

- **Q.** An aqueous feed of A and B (500 liter/min, 200 mmol A/liter, 200 mmol B/liter) is to be converted to product in a mixed flow reactor. The kinetics of the reaction are represented by $A + B \longrightarrow R$, $-r_A = 120\ C_A C_B$ mol/(lit.min). Find the volume of reactor needed for 99% conversion of A to product. **(WINTER 2024, 7 Marks OR)**
- **Q.** At 650 °C phosphine vapor decomposes as follows: $4PH_3 \rightarrow P_4(g) + 6H_2$, $-r_{phos} = (10\ hr^{-1})C_{phos}$. Evaluate the size of plug flow reactor operating at 649 °C and 11.4 atm which is needed for 75% conversion of 10 mol/hr of phosphine in a 2/3 phosphine-1/3 inert feed. **(SUMMER 2026, 7 Marks OR)**
- **Q.** At present the elementary liquid-phase reaction $A + B \longrightarrow R + S$ takes place in a plug flow reactor using equimolar quantities of A and B. Conversion is 96%, $C_{A0} = C_{B0} = 1$ mol/liter. If a mixed flow reactor ten times as large as [Data truncated in source – refer to the original question paper] **(WINTER 2025, 7 Marks)**

3. Reactors in Series and Recycle (Numerical):

- **Q.** An aqueous reactant stream with $C_{A0} = 4$ mol/lit passes through a mixed flow reactor followed by a plug flow reactor. The reaction is 2^{nd} order with respect to A. The volume of plug flow reactor

is 3 times that of the mixed flow reactor. Find the concentration of A at the exit of the plug flow reactor if the concentration of A in the mixed flow reactor is 1 mol/lit. **(WINTER 2022, 7 Marks)**

- **Q.** When elementary 2nd order liquid reaction 2A → 2R carried in a plug flow reactor, operated isothermally, with a recycle ratio of unity, conversion is found to be 66.67%. Determine the conversion if the recycle stream is shut off. **(WINTER 2022, 7 Marks OR)**
- **Q.** A liquid reactant stream (2 mol/liter) passes through two mixed flow reactors in a series. The concentration of A in the exit of the first reactor is 0.7 mol/liter. Find the concentration in the exit stream of the second reactor. The reaction is second-order with respect to A and $V_2/V_1 = 1.5$. **(WINTER 2024, 7 Marks OR)**
- **Q.** A liquid reactant stream (1 mol/liter) passes through two mixed flow reactors in a series. The concentration of A in the exit of the first reactor is 0.5 mol/liter. Find the concentration in the exit stream of the second reactor. The reaction is second-order with respect to A and $V_2/V_1 = 2$. **(WINTER 2025, 3 Marks OR)**

Chapter 4 – Multiple Reactions: Parallel reactions of different orders, Yield and selectivity, Product distribution and design for single and multiple-reactors, Series reactions: first-order reactions and zero-order reactions, Mixed series parallel complex reactions.

Repeated Questions:

1. Yield, Selectivity and Parallel Reactions (Theory):

- **Q.** What is yield, selectivity and product distribution? / Define yield, selectivity and conversion. / Define: Conversion, yield, space time. / Define selectivity with its equation. **(SUMMER 2023, 3 Marks; SUMMER 2025, 3 Marks OR; SUMMER 2025, 3 Marks; SUMMER 2026, 3 Marks)**
- **Q.** Discuss qualitative discussion about the product distribution for reaction in parallel. / Discuss product distribution for parallel reaction. / Qualitative product distribution for reactions in parallel. **(WINTER 2022, 7 Marks; WINTER 2023, 7 Marks; SUMMER 2024, 7 Marks OR; SUMMER 2026, 7 Marks OR)**
- **Q.** Discuss fractional yield, overall yield and selectivity for parallel reaction. / Define Overall Fractional yield and Instantaneous fractional yield for the decomposition of A into product R. **(WINTER 2022, 4 Marks OR; WINTER 2022, 3 Marks OR)**
- **Q.** Discuss parallel reactions with examples. **(SUMMER 2025, 3 Marks)**

2. Series Reactions (Theory):

- **Q.** Qualitative product distribution for irreversible first order reaction in series. **(SUMMER 2025, 7 Marks)**

3. Derivations:

- **Q.** Derive a relation for overall fractional yield in PFR for following reaction in parallel A → R and A → S. **(WINTER 2024, 7 Marks; WINTER 2025, 7 Marks)**
- **Q.** First order unimolecular irreversible reaction in series A ⟶ R ⟶ S takes place with specific reaction rate k1 and k2. Express the variation of concentration of A, R and S with time. Find the expression for the time when formation of R becomes maximum. **(WINTER 2022, 7 Marks OR)**
- **Q.** Derive the rate expression for Irreversible Reactions in Series. **(SUMMER 2026, 7 Marks)**

Other Important Questions:

1. Contacting Patterns and Product Distribution:

- **Q.** Differentiate between contacting patterns in continuous flow operations and noncontinuous operations for various combination of high and low concentration of reactants for maximizing the desired product. **(SUMMER 2025, 7 Marks OR)**
- **Q.** Using separate feeds of A and B sketch the contacting pattern and reactor conditions which would best promote the formation of product R for the following systems of elementary reactions. A + B → R and A → S (Continuous flow reactor) **(WINTER 2024, 3 Marks OR)**

2. Concentration vs Time Diagrams and Maximum Concentration:

- **Q.** Draw schematic diagram of concentration vs time for following reactions: A → R → S [three reaction cases listed in the source; rate-constant labels were lost] [Data truncated in source – refer to the original question paper] **(WINTER 2024, 4 Marks OR)**
- **Q.** Consider the parallel decomposition of A of different orders. Determine the maximum concentration of desired product obtainable in (a) plug flow, (b) mixed flow. (c) Draw schematic diagram of concentration vs time for following reactions. [Diagram required – refer to the original question paper] **(WINTER 2025, 4 Marks OR)**

Chapter 5 – Temperature Effects for Single and Multiple Reactions: Thermal stability of reactors and optimal temperature progression for first order reversible reactions, Adiabatic and heat regulated reactions, Design of non-isothermal reactors, Effect of temperature on product distribution for series and parallel reactions.

Repeated Questions:

1. Optimum Temperature Progression and Adiabatic Operation (Theory):

- **Q.** What do you mean by optimum temperature progression? / Discuss optimum temperature progression in detail. / Describe the optimum temperature progression and its application. **(SUMMER 2023, 3 Marks; SUMMER 2025, 7 Marks OR; WINTER 2025, 3 Marks; SUMMER 2026, 3 Marks OR)**
- **Q.** Derive the relation between conversion and temperature for adiabatic operation. / Derive equation for complete conversion for adiabatic operation. / Show the graphical representation of energy balance equation for adiabatic operation. **(SUMMER 2022, 7 Marks OR; SUMMER 2023, 7 Marks; SUMMER 2025, 4 Marks OR)**
- **Q.** Suggest selection of maximum operating temperature for, i) exothermic irreversible reaction, ii) exothermic reversible reaction, iii) endothermic reversible reactions. **(WINTER 2024, 3 Marks)**
- **Q.** Draw schematic diagram for optimal temperature progression for adiabatic reactions in CSTR and explain its salient features. **(WINTER 2024, 4 Marks)**

2. Temperature Dependency and Activation Energy (Theory):

- **Q.** Discuss the temperature dependence term from Arrhenius Law. / Write a short note on temperature dependency of reaction rate constant from Arrhenius law. Compare the same with transition state and collision theories. / Explain physical significance of activation energy. Also discuss temperature dependency of activation energy using Arrhenius theory. **(SUMMER 2022, 7 Marks; WINTER 2023, 4 Marks; SUMMER 2026, 4 Marks)**
- **Q.** What is activation energy? Explain the importance of activation. / Write short note on Activation Energy. / Discuss sensitivity of activation energy with reference to different parameters. **(SUMMER 2022, 3 Marks; WINTER 2024, 4 Marks; WINTER 2025, 4 Marks)**
- **Q.** List various theories of temperature dependency on rate of reaction and discuss any one in detail. **(SUMMER 2024, 7 Marks)**

3. Chemical Equilibrium and Thermodynamics (Theory):

- **Q.** Define an equilibrium state and discuss characteristics of chemical equilibrium. / Define equilibrium conversion? Discuss. **(SUMMER 2022, 3 Marks OR; WINTER 2023, 3 Marks)**
- **Q.** Discuss the effect of pressure on equilibrium conversion as predicted by thermodynamics keeping temperature fixed. **(WINTER 2023, 7 Marks)**
- **Q.** Discuss the effect of temperature on equilibrium conversion as predicted by thermodynamics keeping pressure constant. / What is effect of temperature and pressure on equilibrium conversion from thermodynamics? **(SUMMER 2022, 4 Marks OR; WINTER 2023, 7 Marks OR)**
- **Q.** Write a short note on equilibrium constants from thermodynamics clearly indicating the equations. / Write in brief about thermodynamic equilibrium constant. **(WINTER 2022, 7 Marks; SUMMER 2024, 4 Marks OR)**

4. Numerical Problems:

- **Q.** Milk is pasteurized if it is heated to 63 °C for 30 min but if it is heated to 74 °C it only needs 15 sec for the same result. Find the activation energy of this sterilization process. **(SUMMER 2025, 4 Marks; SUMMER 2026, 7 Marks)**
- **Q.** At 500 K the rate of a bimolecular reaction is ten times the rate at 400 K. Find the activation energy for this reaction (a) from Arrhenius law, (b) from collision theory, (c) what is the

percentage difference in rate of reaction at 600 K predicted by these two methods? **(SUMMER 2024, 7 Marks)**

- **Q.** The activation energy of a chemical reaction is 17982 cal/mol in the absence of a catalyst, and 11980 cal/mol with a catalyst. By how many times will the rate of the reaction will grow in the presence of a catalyst, if a reaction proceeds at 25 °C? **(SUMMER 2024, 7 Marks OR)**
- **Q.** Find out relation between conversion and temperature (a) Between 0 °C and 100 °C determine the equilibrium conversion of A for the aqueous reaction A ⇌ B, ΔG°_{298} = −3375 cal/mol, $\Delta H^\circ_{r,298}$ = −18,000 cal/mol. Plot a graph between conversion and temperature. **(WINTER 2022, 7 Marks OR)**
- **Q.** At 1100 K n-nonane thermally cracks (breaks down into smaller molecules) 20 times as rapidly as at 1000 K. Find the activation energy for this decomposition. **(SUMMER 2023, 7 Marks)**
- **Q.** The pyrolysis of ethane proceeds with an activation energy of about 300 kJ/mol. How much faster is the decomposition at 650 °C than at 500 °C? **(WINTER 2025, 4 Marks)**

Other Important Questions:

1. Theory:

- **Q.** Discuss effect of temperature on heat of reaction. **(WINTER 2023, 3 Marks OR)**
- **Q.** What the restrictions should be placed on a reactor operating isothermally if we have to obtain fractional conversion of 75% or higher? **(WINTER 2022, 7 Marks OR)**

2. Numerical Problems:

- **Q.** The activation energy of a bimolecular reaction is about 9150 cal/mol. How much faster does this reaction take place at 500 K than at 400 K? **(WINTER 2023, 3 Marks)**

Chapter 6 – RTD theory and analysis of non-ideal reactors

Repeated Questions:

1. RTD Concepts and Non-Ideal Flow (Theory):

- **Q.** Discuss earliness and lateness of mixing in RTD. / Discuss earliness of mixing and lateness of mixing. **(SUMMER 2023, 3 Marks - Page 2; SUMMER 2024, 3 Marks OR)**
- **Q.** What are the various non-idealities that can exist in a reactor? / Discuss the non-ideal flow patterns which may exist in reactor. / Discuss about various types of nonideality exists in different reactors. / Discuss various non-idealities that can be present in a CSTR. / Discuss various non-idealities that can be present in a PFR. **(SUMMER 2022, 4 Marks; SUMMER 2023, 4 Marks - Page 2; SUMMER 2024, 4 Marks; SUMMER 2025, 4 Marks; WINTER 2025, 3 Marks OR; WINTER 2025, 3 Marks)**
- **Q.** Discuss significance of RTD studies. / Uses of RTD studies. / List out characteristics of good tracer. / What is the use of tracer? Discuss desired characteristics of tracer. **(WINTER 2022, 3 Marks OR; WINTER 2023, 4 Marks; SUMMER 2024, 3 Marks; WINTER 2024, 3 Marks)**
- **Q.** Define Residence Time Distribution and explain E-Curve. / Sketch and explain RTD curves for Ideal Plug Flow Reactor and Ideal Mixed flow Reactor. / Draw and discuss C, E and F curve for ideal PFR for pulse input. / Draw C curve and E curve for a pulse input in ideal PFR. **(SUMMER 2022, 3 Marks; WINTER 2022, 3 Marks; WINTER 2023, 4 Marks OR; WINTER 2024, 4 Marks; WINTER 2025, 4 Marks)**
- **Q.** RTD of all the components for ideal PFR is same. Justify this statement. **(WINTER 2024, 3 Marks OR)**
- **Q.** Draw C and E curve for ideal CSTR, PFR with bypass, PFR with dead zone reactions for pulse input. **(WINTER 2024, 4 Marks OR)**
- **Q.** How can you identify dead zone and bypass non-idealities present in CSTR? Explain with suitable schematic diagrams. **(WINTER 2024, 4 Marks)**
- **Q.** From the first principle prove that for a back mix reactor (i) $E_\theta = e^{-\theta}$ and (ii) $F_\theta = 1 - e^{-\theta}$ **(WINTER 2022, 4 Marks OR)**

2. Numerical Problems:

- **Q.** A closed vessel has flow for which dispersion number is 0.3. We wish to represent this vessel by tanks in series model. What value of number of tanks should be selected? **(WINTER 2022, 4 Marks)**
- **Q.** The concentration readings in table below represent a continuous response to a pulse input into a closed vessel which is to be used as a chemical reactor. Calculate the mean residence time of fluid in the vessel $\bar{t}$ and tabulate and plot the exit age distribution E. [Diagram required – refer to the original question paper] **(SUMMER 2023, 7 Marks OR; SUMMER 2025, 3 Marks OR; SUMMER 2026, 7 Marks)**
- **Q.** A pipeline (10 cm I.D., 19.1 m long) simultaneously transports gas and liquid from here to there. The volumetric flow rate of gas and liquid are 60000 cm^3/s and 300 cm^3/s, respectively. Pulse tracer tests on the fluids flowing through the pipe give results as shown in Fig A. below. What fraction of the pipe is occupied by gas and what fraction by liquid? [Diagram required – refer to the original question paper] **(WINTER 2024, 7 Marks; WINTER 2025, 7 Marks)**
- **Q.** A pulse input to a vessel gives the results shown in Fig. below (a) Check the material balance with the tracer curve to see whether the results are consistent. (b) If the result is consistent, determine $\bar{t}$, V and sketch the E curve. [Diagram required – refer to the original question paper] **(WINTER 2024, 7 Marks OR)**

Other Important Questions:

1. Numerical Problems:

- **Q.** Dispersed non coalescing droplets [C_{A0} = 2 mol/liter] react as per the reaction A → R with rate equation $-r_A = kC_A^2$, k = 0.5 lit/(mol.min) as they pass through the contactor. Find the average concentration of A remaining in the droplets leaving the contactor. (Use E = 0.50 for 1 < t < 3) **(SUMMER 2022, 7 Marks OR)**
- **Q.** A pulse of concentrated NaCl solution is introduced as tracer into the fluid entering a vessel (V = 1 m^3, v = 1 m^3/min) and the concentration of tracer is measured in the fluid leaving the vessel. Develop a flow model to represent the vessel from the tracer output data sketched in Fig. as shown below. [Diagram required – refer to the original question paper] **(WINTER 2025, 7 Marks OR)**

2. Theory:

- **Q.** Suggest relative changes in $\bar{t}$ value of various non-idealities present in CSTR. Explain with schematic diagram of C curve for all such cases. **(WINTER 2025, 4 Marks OR)**

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