Bachelor of Chemical Engineering Third Year First Semester Examination 2025

Chemical Reaction Engineering – I

Time: Three hours **Full Marks: 100**

Assume any missing data
All the symbols have their usual meaning
Question 1 is **Compulsory** and Answer any **FOUR** from the rest
Attempt all parts of a question together.

1. **Answer the following questions (5 × 4 = 20)**
   a) Distinguish between homogeneous and heterogeneous reactions. Give one example each the reaction.
   b) Discuss elementary and non-elementary reactions with suitable examples.
   c) For elementary reaction $2A \underset{k_2}{\overset{k_1}{\rightleftharpoons}} R + S$, derive the relation between equilibrium constant (K_c), k_1 and k_2.
   d) Define space velocity and space time of flow reactors.

2. a) For a gas phase reaction at 400K, the rate is reported as $-dp_A/dt = 4.85p_A^2$, atm/hr. [5]
      i) What is the unit of the rate constant?
      ii) What is the value of rate constant with proper unit if the rate equation is expressed as $-dC_A/dt = kC_A^2$, mol/liter-hr?

   b) Find the order and rate constant for the reaction when the half-life periods and initial concentrations for a reaction are reported as below: [5]

$t_{1/2}$, s	C_{A0}, mol/liter
420	0.405
275	0.64

   c) The aqueous solution of ethyl acetate is to be saponified with sodium hydroxide. The initial concentrations of the acetate and NaOH are 0.0568 mol/liter and 0.1 mol/liter, respectively. The values of second order rate constants at 0°C and 20°C are 0.235 and 0.924 liter/mol-min, respectively. The reaction is irreversible. Determine time required to saponify 95% of acetate at 40°C. [10]

3. a) Derive the performance equation for Ideal Plug Flow reactor. [8]

b) A specific enzyme E acts as a catalyst in the fermentation of substrate A (the reactant). The aqueous feed stream of reactant is processed at a rate of 25 liter/min at a given enzyme concentration. Find the volume of plug flow reactor required to achieve 95% conversion of reactant with C_{A0} = 2.0 mol/liter. The stoichiometry and kinetics of the fermentation reaction are given below: [12]

$$A \xrightarrow{\text{enzyme}} R$$

$$-r_A = \frac{0.1C_A}{1+0.5C_A}, \text{ mol/liter-min}$$

4. a) Derive the performance equation for Ideal Mixed Flow reactor. [8]

b) An aqueous feed at a rate of 100 liter/min containing reactant A (C_{A0} = 0.10 mol/liter) is processed in a mixed flow reactor of volume 1000 liters. The stoichiometry and kinetics of the reaction are given below: [12]

$$A \rightleftharpoons R$$

$$-r_A = 0.04C_A - 0.01C_R, \text{ mol/liter-min}$$

Find the equilibrium conversion and the actual conversion in the reactor.

5. a) A unimolecular second order liquid phase reaction was carried out in a mixed flow reactor in which 60% conversion was achieved. It is proposed to use another reactor in series with it. Find the final conversion after a similar sized mixed flow reactor is installed in series with existing one. [10]

b) A conversion of 70% is achieved for the elementary liquid phase reaction $2A \rightarrow R + S$ when carried out in a plug flow reactor operated isothermally with a recycle ratio of 2. Determine the conversion if the recycle stream is turn off. [10]

6. a) The desired liquid phase reaction $A + B \rightarrow R$, $r_R = k_1 C_A^2 C_B^{1.5}$ is accompanied by the undesired side reaction $A + B \rightarrow S$, $r_S = k_2 C_A^{2.5} C_B^{0.5}$. Discuss about what contacting schemes in continuous flow operations would you use to carry above reactions to minimize the production of S? [6]

b) An irreversible first order liquid-phase isomerization reaction is carried out in a mixed flow reactor. Calculate temperature of the reaction mixture and the size of the reactor if the reactor is operated adiabatically for a target conversion of 85%. [14]

Given: Heat of reaction = -350 kJ/mol

Rate constant at 165°C = 0.7, hr^{-1}

Activation energy = 120 kJ/mol

Feed temperature = 20°C

Volumetric flow rate = 0.33 m^3/h

Heat capacities of reactants and products = 1.95 kJ/mol.K

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