B.E. Chemical Engineering Third Year First Semester Examination 2024

Chemical Reaction Engineering – I

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

Assume any missing data

All the symbols have their usual meaning

Note: 1. Question 1 is Compulsory

2. Answer any FOUR from the rest

1. Answer the following questions

a) What are the variables that affect the rate of a reaction? [4]

b) Discuss elementary and non-elementary reactions with suitable examples. [4]

c) Define molecularity and order of an elementary reaction. [4]

d) Define space velocity and space time of flow reactors. [4]

e) What is residence time distribution function in a non ideal flow reactor? [4]

2. a) For a reactant A with initial concentration of C_{A0}, its C_A varies according to $(1/C_A) - (1/C_{A0}) = k\,t$, where '$t$' is time and '$k$' is the rate constant. Derive an expression for the rate of reaction. [5]

b) The liquid phase reaction A → R with C_{A0} =0.2014 mol/L and C_{R0} = 0 proceeds as follows: [15]

Time, min	40	70	120	170	200	∞
C_A, mol/L	0.1450	0.1124	0.0745	0.0550	0.0475	0.0305

Find the rate expression for this reaction. (Solve the problem graphically)

3. a) The laboratory experiment of reaction A → R with F_{A0} = 12.0 mol/s carried out to measure rate vs. conversion of A. Compare the volume of a mixed flow reactor and a plug flow reactor required to achieve 60% conversion. The feed conditions are same for the both the cases and data given below: [15]

X_A	0	0.1	0.3	0.5	0.7
$-r_A$, mol/L.s	0.1820	0.1624	0.1145	0.0712	0.0415

b) What is the physical significance of Damkohler number? State the relation between Damkohler number and rate constant for first and second order reactions. [5]

4. a) A second order liquid phase reaction was carried out in a mixed flow reactor (V_m) in which 60% conversion was achieved. It is proposed to use another reactor in series with it. Find the effect of this addition of reactor on the final conversion of reactant for the following cases: [20]

   i) A similar sized mixed flow reactor (V_m) [i.e. MFR followed by MFR].

   ii) A plug flow reactor of size half of the earlier one being used ($V_p = 1/2V_m$) [i.e. MFR followed by PFR].

5. a) A conversion of 75% 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 unity. Determine the conversion if the recycle stream is turn off. [12]

   b) The desired liquid phase reaction $A + B \rightarrow R$, $r_R = k_1 C_A^{1.5} C_B^{1.7}$ is accompanied by the undesired side reaction $A + B \rightarrow S$, $r_S = k_2 C_A^2 C_B^{0.5}$. Discuss about what contacting schemes in continuous flow and non-continuous operations would you use to carry above reactions to minimize the production of S? [8]

6. a) 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%. [10]

   Given: Heat of reaction = -46000 cal/mol

   Rate constant (k) = 1.8×10^5. exp(-12000/T), s^{-1}

   Feed temperature = 20°C

   Volumetric flow rate = 200 cm^3/s

   Heat capacities of reactants and products = 270 cal/mol.°C

   b) The following data were obtained from a pulse input to a vessel [10]

t, min	0	1	2	3	4	5	6	7	8	9	10	11	12
C, g/m^3	0	1	5	8	10	8	6	4	3	2.2	1.5	0.6	0

Plot the E curve in a graph paper and show the fraction of material leaving the vessel that has spent between 3 and 6 min in the vessel in the plot.