Seat No.: _____ **Enrolment No._____**

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER–VII (NEW) - EXAMINATION – SUMMER 2017

Subject Code: 2170501 **Date: 29/04/2017**

Subject Name: Chemical Reaction Engineering - II

Time: 02.30 PM to 05.00 PM **Total Marks: 70**

Instructions:

1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**

Q.1 (a) Gas containing A contacts and reacts with a semi-infinite slab of the solid B as **07**

$$A_{(g)} + B_{(s)} \rightarrow R_{(g)} + S_{(s)}$$

As reaction progresses, a sharp reaction plane advances slowly into the solid leaving behind it a layer of product through which gaseous A and R must diffuse. Overall then three resistances act in series that of the gas film, the ash layer, and the reaction. Noting that the rate of thickening of the ash layer is proportional to the rate of reaction at that instant or $\frac{dL}{dt} = M(-r_A)$ and the product layer diffusion rate $= D_e \frac{\Delta C}{L}$. If diffusion through ash layer controls, show that $t_{\text{Ash Layer}} = \frac{L^2}{2\,M\,D_e\,C_{Ag}}$

(b) Spherical particles of zinc blende of size R = 1 mm are roasted in an 8% oxygen stream at 900°C and 1 atm. The stoichiometry of the reaction is: $2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$. Assuming that reaction proceeds by the shrinking – core model. Calculate the time needed for complete conversion of a particle and the relative resistance of ash layer diffusion during this operation. ***Data:*** Density of solid, ρ_B = 4.13 gm/cm^3, reaction rate constant, k" = 2 cm/sec, for gases in the ZnO layer, D_e = 0.08 cm^2/sec, molecular weight of Zn = 65.38 g/mol and S = 32 g/mol. Note that film resistance can safely be neglected as long as a growing ash layer is present. **07**

Q.2 (a) Define and discuss enhancement factor and Hatta Modulus for fluid – fluid reactions. **07**

(b) An instantaneous reaction takes place between gas A and spherical solid B giving rise to a hot solid product S and gaseous product R. The rate of consumption of A is same as that of formation of R. Assume that reaction is reversible and gas film resistance is negligible. Show that flux of gas A through the exterior surface of solid is: **07**

$$Q_{AS} = \frac{D_e r_c (C_{Ag} - C_{Ae})}{R(R - r_c)}$$

where D_e is diffusivity of gas A through solid, C_{Ag} & C_{Ae} are bulk and equilibrium concentration of gas A respectively, R & r_c are radius of solid particle and unreacted core respectively. How does above equation is simplified when reaction goes to completion?

OR

(b) Discuss various steps involved in reaction of shrinking spherical particles. Also derive the relation between time and conversion of solid for low gas velocity, if diffusion through gas film controls where small particles are in the Stokes regime. **07**

Q.3 (a) Derive the rate equation for fluid – fluid reaction in the case of pseudo first order fast reaction with higher concentration of constituent B. **07**

(b) Derive and discuss the relation for residence time distribution in ideal batch and plug flow reactors. **07**

OR

Q.3 (a) Hydrogen sulfide (H_2S) of 0.10 % by volume in a carrier gas at 2 MPa is to be absorbed at 20 ^oC by a solution containing 250 mol/m^3 mehtanolamine (MEA). H_2S reacts with MEA irreversibly as per the following reaction. If the diffusivity of MEA in solution is 0.64 times that of H_2S, calculate the enhancement factor for the given reaction. **07**

$$H_2S + MEA \rightarrow HS^- + RNH_3^+$$

Data: $K_{Al,}$ a = 0.03 sec^{-1}, $K_{Ag,}$ a = 6 × 10^{-4} mol/(sec m^3 Pa), Henry's law constant for H_2S in water H_A = 10 Pa m^3/mol.

(b) Derive relation for the tank – in – series model along with normalized RTD function. **07**

Q.4 (a) List out all the assumptions and derive Langmuir adsorption isotherm equation for catalytic reaction. Also discuss the significance for failure of Langmuir model and necessary modification. **07**

(b) To remove oxides of nitrogen (NO) from automobile exhaust, a scheme has been proposed that uses unburned carbon monoxide in the exhaust to reduce the NO over a solid catalyst, as per the reaction: CO + NO → Products (CO_2, N_2). Experimental data for a particular solid catalyst indicate that the reaction rate can be well represented over a large range of temperature by: **07**

$$-r_N = \frac{k\, P_N\, P_C}{\left(1 + k_1\, P_N + k_2\, P_C\right)^2}$$

(i) Suggest an adsorption – surface reaction – desorption mechanism consistent with rate equation. (ii) It is desirable to operate with a very large stoichiometric excess of CO to minimize the catalytic reactor volume. Do you agree or disagree? Justify.

OR

Q.4 (a) Write in brief about product distribution in multiple reactions. **07**

(b) The rate law hydrogenation (H) of ethylene (E) to form ethane (A) over a cobalt – molybdenum catalyst is: **07**

$$-r_E = \frac{k\ P_E\ P_H}{1 + k_E\ P_E}$$

Suggest a mechanism and rate limiting step consistent with the rate law.

Q.5 **(a)** Answer any three of the following in brief. **06**

(i) Turnover frequency and dispersion of catalyst (ii) Characteristics and selectivity of catalyst (iii) Monolithic catalyst (iv) Molecular sieves.

(b) Write a brief note on experimental reactors for solid catalyzed reactions. **08**

OR

Q.5 **(a)** Write short note on: catalyst promoters, inhibitors and poisons. **07**

(b) Discuss about the determination of surface area of catalysts. **07**

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