

# B.M.S. College of Engineering, Bengaluru-560019

Autonomous Institute Affiliated to VTU

## September / October 2023 Supplementary Examinations

**Programme: B.E.**

**Branch: Chemical Engineering**

**Course Code: 19CH6DCCR2**

**Course: Chemical Reaction Engineering-II**

**Semester: VI**

**Duration: 3 hrs.**

**Max Marks: 100**

**Date: 15.09.2023**

**Instructions:** 1. Answer any FIVE full questions, choosing one full question from each unit.  
2. Missing data, if any, may be suitably assumed.

### UNIT - I

- 1 a) A pulse tracer experiment was carried out to understand the non-ideal behavior in a mixed flow reactor, apply the suitable material balance and derive an expression to estimate the RTD value in the reactor. **10**
- b) A reactor with dividing baffles is to be used to run the reaction  $A \rightarrow R$  with  $-r_A = 0.15C_A$  **10**  
 $\frac{\text{mol}}{\text{lit. min}}$ . A pulse tracer test was carried out gives the following output curve.

Time, min	0	10	20	30	40	50	60	70
Concentration reading, mol/lit	35	38	40	40	39	37	36	35

- Find the area under the C versus t curve analytically and graphically.
- Construct the E versus t curve.
- How many tanks in series is this vessel is equivalent to the dividing baffles?

### UNIT - II

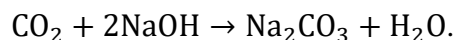
- 2 a) Derive an expression to estimate the reaction rate for a fluid-fluid fast second order reaction with respect to mass transfer. **10**
- b) Spherical particles of zinc blende of size  $R = 1$  mm are roasted in an 8% oxygen stream at  $900^\circ\text{C}$  and 1 atm. The stoichiometry of the reaction is  $2\text{ZnS} + 3\text{O}_2 \rightarrow 2\text{ZnO} + 2\text{SO}_2$ . Assume that reaction proceeds by the shrinking-core model. **10**
- Calculate the time needed for complete conversion of a particle and the relative resistance of ash layer diffusion during this operation.
  - On doubling the particle size from  $R$  to  $2R$  the time for complete conversion triples. What is the contribution of ash diffusion to the overall resistance for particles of size?

**Important Note:** Completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages. Revealing of identification, appeal to evaluator will be treated as malpractice.

Data: density of solid =  $4.13 \text{ g/cm}^3$ , reaction rate constant,  $k'' = 2 \text{ cm/s}$ , and for gases in the ZnO layer,  $D_e = 0.08 \text{ cm}^2/\text{s}$ .

**OR**

- 3 a) At high pressure  $\text{CO}_2$  is absorbed into a solution of NaOH in a packed column. The instantaneous reaction is as follows, **10**



At a point in the column where  $P_A = 2 \times 10^5 \text{ Pa}$  and solution is 0.2 N.

Find the rate of absorption, the controlling resistance, and what is happening in the liquid film.

Data given:  $k_{Al} \times a = 25.0 \frac{1}{\text{h}}$ ;  $k_{Ag} \times a = 0.8 \frac{\text{mol}}{\text{m}^3 \times \text{h} \times \text{Pa}}$ ;

$D_A = 1.0 \times 10^{-9} \frac{\text{m}^2}{\text{s}}$ ;  $D_B = 1.0 \times 10^{-9} \frac{\text{m}^2}{\text{s}}$ ;  $f_1 = 0.1$ ; and

$H_A = 3000 \frac{\text{m}^3 \times \text{Pa}}{\text{mol}}$ ;  $a = 100 \frac{\text{m}^2}{\text{m}^3}$

- b) Develop an expression to estimate the rate for a fluid-solid reaction, assuming gas film as the rate controlling step with a neat diagram. **10**

### UNIT - III

- 4 a) Illustrate the steps involved in a catalytic reaction and explain the importance of major steps used to develop the kinetic equation for any catalytic reactions. **06**

- b) Consider the given reaction scheme for adsorption of chlorine on catalyst surface and reacting with the other reactant carbon monoxide to form a product. From the given reaction schemes, find the suitable rate controlling step whose rate is same as experimental rate expression. **08**

$$r_s = \frac{k_2 K_1 C_t P_{\text{Cl}_2} P_{\text{CO}}}{1 + K_1 P_{\text{Cl}_2} + K_2 P_{\text{COCl}_2}}$$

Adsorption step :  $\text{Cl}_2 + \text{S}^* \rightleftharpoons \text{Cl}_2\text{S}^*$

Reaction step :  $\text{CO} + \text{Cl}_2\text{S}^* \rightarrow \text{COCl}_2\text{S}^*$

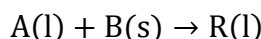
Desorption step :  $\text{COCl}_2\text{S}^* \rightleftharpoons \text{COCl}_2 + \text{S}^*$

- c) Explain the principle of nitrogen desorption method and list the equations used to estimate the pore size with their physical significance. **06**

### UNIT - IV

- 5 a) Derive an experimental rate expression for independent deactivation carried out in batch of solid and batch flow of fluid system. **06**

- b) Dilute A diffuses through a stagnant liquid film onto a plane surface consisting of B, and reacts to produce R, which diffuses back into the mainstream. Develop the overall rate expression for the 1<sup>st</sup> order liquid-gas reaction with respect to A. The reaction is as follows, which is occurring on the flat surface. **06**



- c) An experimental rate of decomposition of A was measured in the presence of a catalyst. Assume that the reaction is 1<sup>st</sup> order and estimate the following. **08**
- Check if the film resistance to mass transfer influences the rate?
  - Check if the run is carried out in the regime of strong pore diffusion?
  - Would you expect to have temperature variations within the pellet or across the gas film?

Data:

For the spherical particle:  $d_p = 2.4 \text{ mm}$ ,  $D_e = 5 \times 10^{-5} \frac{\text{m}^2}{\text{s}}$ ,

and  $k_{\text{eff}} = 5 \times 10^{-5} \frac{\text{m}^3}{\text{s mol cat K}}$

For the gas film surrounding the pellet:  $h = 1.6 \frac{\text{m}^3}{\text{s m}^2 \text{ cat K}}$ , and  $K_g = 300 \frac{\text{m}^3}{\text{s m}^2 \text{ cat}}$

For the reaction:  $\Delta H_r = -160 \frac{\text{kJ}}{\text{mol A}}$ ,  $C_{A0} = 20 \frac{\text{mol}}{\text{m}^3}$ , and  $-r_A''' = 10^5 \frac{\text{mol}}{\text{s m}^3 \text{ cat}}$ .

**OR**

- 6 a) Derive an experimental rate expression for independent deactivation carried out in batch of solid and changing plug flow of fluid system. **08**
- b) Derive a relationship to estimate the effectiveness factor for a 1<sup>st</sup> order catalytic reaction in a single cylindrical pore. State all the assumptions made to derive the expression. **12**

#### **UNIT – V**

- 7 a) Derive a rate expression to estimate the kinetic behavior of slurry reactor. **10**
- b) A Solid catalyzed reaction  $A \rightarrow 4R$ , is conducted at 3.2 atm and 117°C in a plug flow reactor containing 10g of catalyst. The feed to the reactor is partially converted product, flowing at a rate of 20 L/h of pure unreacted A. The experimental data is given below **10**

Run	1	2	3	4
$C_{Ain}(\text{mol/lit})$	0.10	0.08	0.06	0.04
$C_{Aout}(\text{mol/lit})$	0.084	0.07	0.055	0.038

Find the rate equation for this reaction.

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