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

Autonomous Institute Affiliated to VTU

September / October 2023 Supplementary Examinations

Programme: B.E. **Semester: VI**
Branch: Chemical Engineering **Duration: 3 hrs.**
Course Code: 19CH6DCCR2 **Max Marks: 100**
Course: Chemical Reaction Engineering-II **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 $-r_A = 0.15C_A$ $\frac{mol}{lit\,.\,min}$. A pulse tracer test was carried out gives the following output curve. **10**

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

i. Find the area under the C versus t curve analytically and graphically.
ii. Construct the E versus t curve.
iii. 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 °C and 1 atm. The stoichiometry of the reaction is $2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$. Assume that reaction proceeds by the shrinking-core model. **10**

i. Calculate the time needed for complete conversion of a particle and the relative resistance of ash layer diffusion during this operation.
ii. 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?

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

OR

3 a) At high pressure CO_2 is absorbed into a solution of NaOH in a packed column. The instantaneous reaction is as follows, **10**

$CO_2 + 2NaOH \rightarrow Na_2CO_3 + H_2O$.

At a point in the column where $P_A = 2 \times 10^5$ 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: $k_{Al} \times a = 25.0\ \frac{1}{h}$; $k_{Ag} \times a = 0.8\ \frac{mol}{m^3 \times h \times Pa}$;

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

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

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**

$$r_S = \frac{k_2 K_1 C_t P_{cl2} P_{CO}}{1 + K_1 P_{cl2} + K_2 P_{COCl2}}$$

$$\text{Adsorption step} : Cl_2 + S^* \rightleftharpoons Cl_2S^*$$
$$\text{Reaction step} : CO + Cl_2S^* \rightarrow COCl_2S^*$$
$$\text{Desorption step} : COCl_2S^* \rightleftharpoons COCl_2 + S^*$$

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 1st order liquid-gas reaction with respect to A. The reaction is as follows, which is occurring on the flat surface. **06**

$$A(l) + B(s) \rightarrow R(l)$$

c) An experimental rate of decomposition of A was measured in the presence of a catalyst. Assume that the reaction is 1st order and estimate the following. **08**

i. Check if the film resistance to mass transfer influences the rate?
ii. Check if the run is carried out in the regime of strong pore diffusion?
iii. Would you expect to have temperature variations within the pellet or across the gas film?

Data:

For the spherical particle: $d_p = 2.4$ mm, $D_e = 5 \times 10^{-5}\ \frac{m^3}{h\ m\ cat}$,

and $k_{eff} = 5 \times 10^{-5}\ \frac{kJ}{h\ m\ cat\ K}$

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

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

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 1st 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℃ 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}**(mol/lit)**	0.10	0.08	0.06	0.04
C_{Aout} **(mol/lit)**	0.084	0.07	0.055	0.038

Find the rate equation for this reaction.

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