BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI
(END SEMESTER EXAMINATION)

CLASS: MTECH **SEMESTER : I**
BRANCH: BT **SESSION : MO/2022**

SUBJECT: BE503 ADVANCED REACTION ENGINEERING

TIME: 3:00 Hours **FULL MARKS: 50**

INSTRUCTIONS:
1. The question paper contains 5 questions each of 10 marks and total 50 marks.
2. Attempt all questions.
3. The missing data, if any, may be assumed suitably.
***4*. Before attempting the question paper, be sure that you have got the correct question paper.**
5. Tables/Data hand book/Graph paper etc. to be supplied to the candidates in the examination hall.

Q.1(a) What do you mean by rate controlling step in heterogeneous reactions? [2]
Q.1(b) A non-porous catalyst particle is of size 2 microns and density is 2 g/cm^3. Calculate the external surface area per gram of the particle. [3]
Q.1(c) Dilute A diffuses through a stagnant liquid film onto plane surface of solid B. On this plain surface A and B react to field liquid product B which diffuses leak. Develop the overall rate of expression. [5]
A*(l)* + B(s) $\rightarrow$ A(*l*) second order with respect to A *(l)* – all else remain unchanged.

Q.2(a) What are promoters and inhibitors? [5]
Q.2(b) Discuss in detail the nature of catalyst and how it increases the rate of reaction [5]
Q.2(c) List some of the problems that would be encountered in the operation of a fluidized catalytic reactor

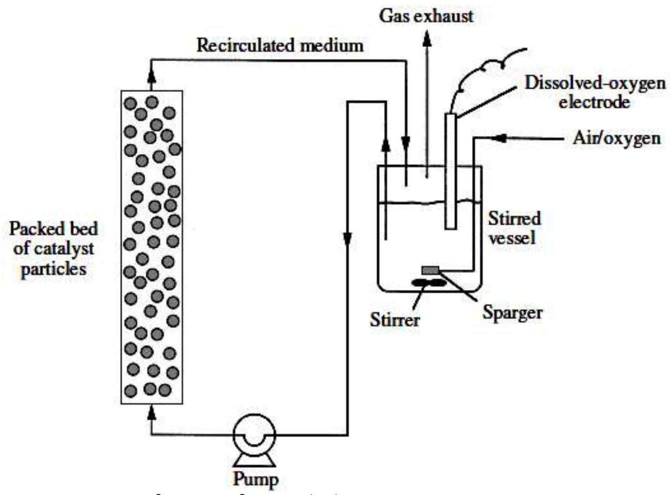
Q.3(a) What is the effect of catalyst pellet size on the effectiveness factor? [5]
Q.3(b) What is effective diffusivity? Express the relationship between diffusion coefficient and effective diffusivity with units. [5]
Q.3(c) The following kinetic data are obtained in a basket type mixed reactor. The catalyst is porous. Assuming isothermal behaviours interpret the data in terms of controlling resistances.
Data:

Pellet diameter	Concentration in reactant in the exit stream	Spinning rateof baskets	Measured reactions rate □r'_A
1	1	High	3
2	1	Low	1
3	1	High	1

Q.4(a) Explain the resistances that would be encountered during the burning of coal. [5]
Q.4(b) How do you classify the kinetic regimes in gas-liquid reactions? [5]
Q.4(c) What are the steps occurring when gaseous reactant is transported to the surface of the solid particles? Explain the transport phenomena with the aid of a diagram.

Q.5 Mass transfer effects in plant cell culture [5]
Suspended *Catharanthus roseus* cells form spherical aggregates approximately 1.5 mm in diameter. Oxygen uptake is measured using the apparatus of the figure shown; medium is recirculated with a superficial liquid velocity of 0.83 cm s^{-1}. At a bulk concentration of 8 mg $^{-}$*1,* oxygen is consumed at a rate of 0.28 mg per g wet weight of cells per hour. Assume that the density and viscosity of the medium are similar to water and the specific gravity of wet cells is 1. The effective diffusivity of oxygen in the aggregates is $9x10^{-6}$ cm^2 s^{-1}, or half that in the medium. Oxygen uptake follows zero-order kinetics.
Q.5(a) Does external mass transfer affect the oxygen uptake rate? [5]
Q.5(b) To what extent does internal mass transfer affect oxygen uptake?
Q.5(c) Roughly, what would you expect the profile of oxygen concentration to be within the aggregates?
<u>Data for Q 5:</u>
Fig1: Batch recirculation reactor for measuring the rate of oxygen uptake by immobilised cells or enzymes

PTO



1. μ_L Viscosity of water at 20^{0}C = 10^{-3}kg m^{-1}s^{-1}
2. Re_p = (particle) Reynolds number:

$$\frac{D_P\, u_{pL}\, \rho_L}{\mu_L}$$

3. Sherwood number for spherical particles in packed beds:

$$Sh = 0.95\, Re_P^{0.5}\, Sc^{0.33}$$

4. Schmidt number:

$$Sc = \text{Schmidt number} = \frac{\mu_L}{\rho_L\, \mathscr{D}_{AL}}$$

5. Sherwood number for packed bed system:

$$Sh = 0.95\, Re_P^{0.5}\, Sc^{0.33}$$

$$Sh = \text{Sherwood number} = \frac{k_S D_P}{\mathscr{D}_{AL}}$$

6. Observable moduli for external mass transfer:

Sphere	$\Omega = \frac{R}{3}\frac{r_{A,obs}}{k_S\, C_{Ab}}$
Flat plate	$\Omega = b\frac{r_{A,obs}}{k_S\, C_{Ab}}$

7. $$\frac{C_{As}}{C_{Ab}} = 1 - \frac{V_P}{S_x}\frac{r_{A,obs}}{k_S\, C_{Ab}}$$
8. Observable moduli correlation from literature:

$$\Omega = \frac{V_P}{S_x}\frac{r_{A,obs}}{k_S\, C_{Ab}}$$

9. From literature: For Zero order reactions: ϕ = 0.73; η = close to 1
10. Consider the following correlation, maximum particle radius for $C_A > 0$ as:

$$R_{max} = \sqrt{\frac{6\mathscr{D}_{Ae}C_{As}}{k_0}}$$

11. Observable Thiele moduli:

Sphere	$\Phi = \left(\frac{R}{3}\right)^2 \frac{r_{A,obs}}{\mathscr{D}_{Ae}C_{As}}$
Flat plate	$\Phi = b^2 \frac{r_{A,obs}}{\mathscr{D}_{Ae}C_{As}}$