

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

CLASS: MTECH  
BRANCH: BIOTECHNOLOGY

SEMESTER : I  
SESSION : MO/2025

**SUBJECT: BE503 ADVANCED REACTION ENGINEERING**

TIME: 3 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 handbook/Graph paper etc. to be supplied to the candidates in the examination hall.
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- |   |        | CO | BL  |
|---|--------|----|-----|
| Q.1(a) What are the various contacting patterns for heterogeneous reaction?   | [3]    | 1  | 3   |
| Q.1(b) Dilute A diffuses through a stagnant liquid film onto plane surface of solid B. On this plain surface A and B react to yield liquid product R which diffuses back through the film into the mainstream. Develop the overall rate of expression for L/S reaction.<br>$A(l) + B(s) \rightarrow R(l)$ first order with respect to A (l) | [7]    | 1  | 3,4 |
| Q.2(a) (i) What is a bi-dispersed catalyst?   | [2x2.5 | 2  | 2   |
| (ii) Differentiate between a catalyst promoter and a deactivator  | =5]    |    | 2   |
| Q.2(b) (i) Does a catalyst alter the equilibrium conversion of a chemical reaction? Explain.  | [2x2.5 | 2  | 3,4 |
| (ii) Define the effectiveness factor of a catalyst. Can the effectiveness factor of a catalyst be greater than one? Explain   | =5]    |    | 2,3 |
| Q.3(a) (i) A porous catalyst particle is soaked in reactant A. Discuss the dependency factors of the rate of reaction of A.   | [2.5]  | 3  | 3,4 |
| (ii) What is effective diffusivity? Express the relationship between diffusion coefficient and effective diffusivity  | [2.5]  |    |     |
| Q.3(b) The following kinetic data were obtained in a basket-type mixed reactor. The catalyst is porous. Assuming isothermal behaviours, interpret the data in terms of controlling resistances.   | [5]    | 3  | 3,4 |

Data:

Pellet Diameter (mm)	Concentration of the reactant A in the exit stream mol/lit	Spinning rate of the basket	Measured reaction rate, mol A / hr.kg catalyst
1	1	High	3
2	1	Low	1
3	1	High	1

- |   |     |   |     |
|---|-----|---|-----|
| Q.4(a) How do you classify the kinetic regimes in gas-liquid reactions?                                       | [3] | 4 | 3   |
| Q.4(b) It is proposed to remove CO <sub>2</sub> from the air by counter-current contact with water at 250 °C. | [7] | 4 | 3,4 |

- (i) Find the resistance of the gas and liquid film for this operation.
- (ii) Suggest the simplest form of rate equation for tower design.

Data:

For CO<sub>2</sub> between air & water,  
 $K_g a = 0.80 \text{ mol / (h.m}^3\text{.Pa)}$   
 $K_l a = 25 \text{ h}^{-1}$   
 $H = 3000 \text{ ( Pa.m}^3\text{)/mol}$

PTO

Q.5(a) (i) What are the consequences of mass transfer limitations on immobilised cells' growth and activity? [2x2 = 4] 5 3,4

(ii) What is the Damköhler number ( $D_a$ ) and how does it relate to mass transfer in immobilised enzymes?

Q.5(b) *Effect of oxygen transfer on recombinant cells* [3x2=6] 5 3,4

Recombinant *E. coli* cells contain a plasmid derived from pBR322 incorporating genes for the enzymes  *$\beta$ -lactamase* and catechol 2,3-dioxygenase from *Pseudomonas putida*. To produce the desired enzymes, the organism requires aerobic conditions. The cells are immobilised in spherical beads of carrageenan gel.

The effective diffusivity of oxygen is:  $1.4 \times 10^{-9} \text{ m}^2 \text{ s}^{-1}$ . Oxygen uptake is zero-order with intrinsic rate constant  $10^{-3} \text{ mol s}^{-1} \text{ m}^{-3}$  of particle. The concentration of oxygen at the surface of the catalyst is  $8 \times 10^{-3} \text{ kg m}^{-3}$ . Cell growth is negligible.

- a) What is the maximum particle diameter for aerobic conditions throughout the catalyst particles?
- b) For particles half the diameter calculated in (a), what is the minimum oxygen concentration in the beads?
- c) The density of cells in the gel is reduced by a factor of five. If the specific activity of the cells is independent of cell loading, what is the maximum particle size for aerobic conditions?

Data:

1. For spherical particles:

$$R_{\max} = \sqrt{\frac{6D_{Ae}C_{As}}{k_0}}$$

2. Observable Thiele Modulus:

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

3. Minimum Intra catalyst substrate concentration for Zero order kinetics

<b>Sphere</b>	
$C_{A,\min} = 0$	for $\Phi \geq 0.667$
$C_{A,\min} = C_{As} \left(1 - \frac{3}{2}\Phi\right)$	for $\Phi < 0.667$
<b>Flat plate</b>	
$C_{A,\min} = 0$	for $\bar{\Phi} \geq 2$
$C_{A,\min} = C_{As} \left(1 - \frac{1}{2}\bar{\Phi}\right)$	for $\bar{\Phi} < 2$