BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI
(MID-SEMESTER EXAMINATION MO/2024)

CLASS: BTECH **SEMESTER: V**
BRANCH: CHEMICAL ENGINEERING **SESSION: MO/2024**

SUBJECT: CL325 CHEMICAL REACTION ENGINEERING -II

TIME: 02 Hours **FULL MARKS: 25**

INSTRUCTIONS:
1. The question paper contains 5 questions each of 5 marks and total 25 marks.
2. Attempt all questions.
3. The missing data, if any, may be assumed suitably.
***4*. Tables/Data handbook/Graph paper etc., if applicable, will be supplied to the candidates**

			CO	BL
Q.1	A hydrogenation catalyst is prepared by soaking alumina (Al_2O_3) particles (100 to 150 mesh size) in an aqueous $NiNO_3$ solution. After drying and reduction, the particles contain about 7 wt% NiO. This catalyst is then made into large cylindrical pellets for rate studies. The gross measurements for one pellet are: Mass = 5 g, Diameter = ½ in, and Thickness = ½ in. The Al_2O_3 particles contain micropores, and the pelleting process introduces macropores surrounding the particles. The macropore volume of the pellet is 0.50 cm^3, and the micropore volume is 0.40 cm^3/g of particles. From this information, calculate: (i) solid fraction, (ii) density of the particles, (iii) density of the solid phase, (iv) void fraction of the particles, and (v) micropore void fraction in the pellet.	[5]	CO1	3
Q.2(a)	What are the differences between Physisorption and Chemisorption?	[2]	CO1	2
Q.2(b)	Carbon monoxide (CO) is known to follow dissociative adsorption over iron (Fe) surface as shown below:	[3]	CO2	3

$$CO + -Fe-Fe-Fe- \rightarrow \begin{matrix} C & O \\ | & | \\ -Fe- & -Fe-Fe- \end{matrix}$$

Derive an expression for the adsorption of adsorbed CO species.

Q.3	Hydrogen and Toluene (T) react over a solid catalyst to form Methane (M) and Benzene (B).	[5]	CO2	3

$$C_6H_5CH_3(g) + H_2(g) \rightarrow C_6H_6(g) + CH_4(g)$$

The mechanism of the reaction is as follows:

Adsorption:	$T_{(g)} + S \rightleftharpoons T.S$
Surface reaction:	$H_{2(g)} + T.S \rightleftharpoons B.S + M_{(g)}$
Desorption:	$B.S \rightleftharpoons B_{(g)} + S$

K_T and Ks are adsorption and surface reaction equilibrium constants, respectively. K_B is the reciprocal of the desorption equilibrium constant. Assuming surface reaction is rate limiting, derive the below rate kinetics by assuming suitable assumptions:

$$-r_T = \frac{kP_{H2}P_T}{(1 + K_BP_B + K_TP_T)}$$

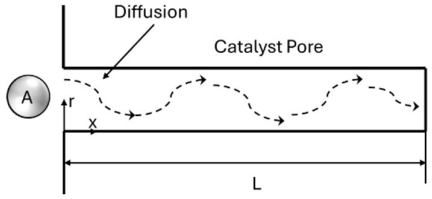
Q.4(a)	Write all the steps in a heterogeneous catalytic reaction for a porous catalyst.	[2]	CO2	2
Q.4(b)	Briefly explain the assumptions and the generic expression of Langmuir- Hinshelwood-Hougen-Watson (LHHW) kinetics.	[3]	CO2	2

PTO

Q.5(a) Define the effectiveness factor for a catalyst. Why is the species concentration profile required within the particle to evaluate the effectiveness factor? [2] CO3 2

Q.5(b) Consider a cylindrical catalyst pore of length L, in which a species A diffuses (Diffusivity = *D*) and reacts on the surface by a first-order reaction [3] CO3 3

$$A \rightarrow \text{Product}, \; -r_A = kC_A$$



(i) Derive the following governing differential equation for the concentration profile inside the pore.

$$\frac{d^2C_A}{dx^2} - \frac{k}{\mathcal{D}}C_A = 0$$

(ii) State the boundary conditions (B.Cs) to solve the differential equation.

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