CLASS:	B. TECH	SEMESTER: V
BRANCH:	CHEMICAL ENGINEERING	SESSION: MO/2024

SUBJECT: CL325 CHEMICAL REACTION ENGINEERING-II

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.

			CO	BL
Q.1(a)	Write the name of catalyst preparation techniques. Describe one of those techniques in detail. Also, name two industrial catalytic processes and the catalyst used.	[5]	CO1	2
Q.1(b)	Determine the specific surface area of activated carbon in m^2/g using the adsorption data for carbon dioxide at $0°C$. The density of liquefied CO_2 at $0°C$ is 1.02 g/cm^3. The BET analysis for 0.625 g of the activated carbon adsorbent gives an intercept of 0.0004 cc^{-1} and a slope of 0.015 cc^{-1} at STP. Assuming cylindrical pore model, calculate the pore volume in cc/g for the mean pore radius of 10 Å.	[5]	CO1	3
Q.2(a)	How is the observed rate of reaction different from the intrinsic rate of reaction in case of heterogenous reaction? Explain with respective rate equations. Justify with a sketch the concentration profiles of a reactant, if a reaction on a porous catalyst is (i) kinetically controlled, (ii) external mass-transfer controlled, (iii) Internal-diffusion controlled.	[5]	CO2	2
Q.2(b)	Ethanol can be produced by catalytic vapor phase hydration of ethylene at 135 atm and 573 K.	[5]	CO2	3

$$C_2H_4 + H_2O \rightleftharpoons C_2H_5OH \qquad \text{Or symbolically} \quad A + B \rightleftharpoons R$$
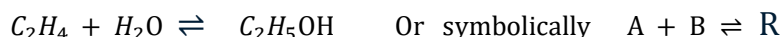
The rate expression for this reaction is

$$-r_A' = \frac{zk_Ak_B(p_Ap_B - p_R/K)}{(1 + k_Ap_A + k_Bp_B)^2} \quad , \quad \frac{mol}{g\,cat.h}$$

where $z = 0.018$, $k_A = k_B = 0.003$. The equilibrium constant is given by: $RT \ln K = 30T - 9730$, where $R = 1.987$ cal/(mol.K). For a 5% of conversion of A, calculate the rate of reaction in mol/(g cat.h).

Q.3(a)	Give one example for each case of the following types of reactions. S and F refer to solid and fluid, respectively. (i) $S + F \rightarrow S + F$, (ii) $S + F \rightarrow S$, (iii) $S + F \rightarrow F$, and (iv) $F \rightarrow S + F$	[2]	CO3	2
Q.3(b)	Explain the key assumptions of the Shrinking Core Model.	[3]	CO3	2
Q.3(c)	Calculate the time required to completely burn a coal particle (R = 5 mm, ρ_B = 2200 mol/m^3, k = 20 m/s) in a 7.0 mmol/m^3 oxygen stream, for the cases of (i) The film/ash diffusion offers no resistance to transfer and reaction. (ii) The rate is limited by gas the film.	[5]	CO3	3

Data: D_{O2} = $4×10^{-5}$ m^2/s, Velocity of O_2 stream= 0.1 cm/s. Use the following correlation for calculating k_g

$$Sh = 2 + 0.6Re^{0.5}Sc^{0.33}$$

where, $Sc = \mu\rho/D_{O2}$, $Sh = k_gd_p/D_{O2}$, $Re = \rho u d_p/\mu$, ρ of O_2 = 1.04 kg/m^3, μ of O_2 = $2.28×10^{-5}$ Pa-s

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Q.4(a)	Explain the ways which can be adopted to avoid both external and internal mass transfer resistances in a catalytic reaction.	[2]	CO4	2
Q.4(b)	A reaction A → R takes place on a porous catalyst pellet (d_P = 6 mm, D_e = 10^{-6} m^3/m cat. s). Calculate the effectiveness factor of the catalyst if the concentration of reactant at the surface of the particle is 100 mol/m^3 and the diffusion-free kinetics are given by $-r_A''' = 0.1C_A{}^2$ $mol/(m^3\ cat.s)$.	[3]	CO4	3
Q.4(c)	A first-order isothermal heterogeneous reaction $A \to B$ is carried out using a porous spherical catalyst under strong pore diffusion regime. At a bulk concentration of A at 0.05 mol/m^3, the observed reaction rate in a 4 mm diameter catalyst particle was found to be 0.2 mol $s^{-1}m^{-3}$ catalyst volume. What is the observed reaction rate in mol s^{-1} L^{-1} catalyst volume in a 6 mm diameter catalyst particle for the bulk concentration of A at 0.15 mol/m^3	[5]	CO4	3
Q.5(a)	Carbon dioxide (CO_2) gas at a certain partial pressure (p_{CO2}) is dissolved in an aqueous Sodium hydroxide (NaOH) solution by reactive absorption, leading to the formation of carbonates and bicarbonates of sodium. The rate of the reaction in the NaOH solution (liquid) is given by $-r_{CO2}$= $k_{CO2}C_{NaOH}$. Further, it can be assumed that the interfacial concentration of CO_2 is at equilibrium and hence given by $p_{CO2,i}$ =$HC_{CO2,i}$, where H is the Henry's constant.	[5]	CO5	3

Q.5(a) (continued)

Additional information:
Gas-side mass-transfer coefficient: $k_{CO2,g}$, liquid-side mass-transfer coefficient: $k_{CO2,l}$, Gas-liquid Interfacial Area: a, Enhancement factor: E, Liquid volume fraction: f_l

Based on the information provided (i) Draw the concentration profiles for CO_2 and NaOH, (ii) Show and explain that the overall rate of disappearance of CO2 is given by:

$$-r_{CO}''''_2 = \frac{p_{CO_2}}{\left[\dfrac{1}{k_{CO_2,g}a} + \dfrac{H}{Ek_{CO_2,l}a} + \dfrac{H}{f_l k C_{NaOH}}\right]}$$

Q.5(b)	Aqueous acetone (C_{BO} = 1000 mol/m^3 l, v_l, = 10^{-4} m^3 l/s) and hydrogen (1 atm, v_g = 0.04 m^3 g/s, H_A = 36845 Pa.m^3 l/mol) are fed to a reactor packed with a catalyst (d_P = 5 mm cat, p_s = 4500 kg/m^3, f_s = 0.6, D_e = 8×10^{-10} m^3 l/(m cat. s). The rate is given by $-r_A' = k'C_A{}^{1/2}C_B{}^0$ $with\ k' = 2.35 \times 10^{-3}\ m^3\ l/(kg.s)(mol/m^3\ l)^{0.5}$. Calculate the rate of reaction in mol/(m^3 r. s). Data: The mass transfer rate constants are estimated to be$(k_{Ai}a_i)_{g+l} = 0.02\ m^3 l/m^3\ r.s$, $(k_{Ac}a_c) = 0.05\ m^3\ l/m^3\ r.s$.	[5]	CO5	3

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