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

CLASS: B.TECH. **SEMESTER: VI**
BRANCH: CHEMICAL ENGINEERING AND CHEMICAL ENGINEERING (P&P) **SESSION: SP/2023**

SUBJECT: CL320 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 hand book/Graph paper etc. to be supplied to the candidates in the examination hall.

		Marks	CO	BL
Q.1(a)	Briefly describe the desired characteristics of a catalyst. Also discuss the importance of catalysis and catalyst technology.	[5]	1	2
Q.1(b)	A Ni/Al_2O_3 catalyst is prepared by impregnation of Al_2O_3 powder with an aqueous $Ni(NO_3)_2$ solution. The catalyst is formed into 5 mm X 5 mm cylindrical pellets for activity testing. The following properties of the finished catalyst were measured by the methods indicated: ρ_b (bulk density) = 1.030 g/cm^3 [Tap density method], ρ_S (skeletal density) = 3.801 g/cm^3 [He-displacement], $V_{mesopore}$ = 0.230 cm^3/g [N_2 adsorption], $V_{bed,void}$ = 0.385 cm^3/g [Hg-displacement]. From the measured properties, calculate the following: (a) Bulk or Bed porosity, (b) Pellet density, (c) Specific pore volume, (d) Pellet porosity, (e) Specific macropore volume.	[5]	1	3
Q.2(a)	Hydrogen and toluene (T) react over a solid mineral catalyst to form methane (M) and benzene (B). $$C_6H_5CH_3 + H_2 \rightarrow C_6H_6 + CH_4$$ We wish to design a packed-bed reactor to process a feed (40 atm, 640 °C) containing 30% toluene and, 70% hydrogen. The mechanism proposed for the reaction is: Adsorption: $T(g) + S \rightleftharpoons T.S$ (K_T = adsorption equilibrium constant) Surface reaction: $H_2(g) + T.S \rightarrow B.S + M(g)$ Desorption: $B.S \rightleftharpoons B(g) + S$ (K_B = adsorption equilibrium constant) (a) Assuming surface-reaction is limiting, derive $$-r = \frac{kP_{H2}P_T}{1 + K_BP_B + K_TP_T}$$ (b) What is the fraction of vacant sites at 60% conversion? (K_T = 1.038; K_B = 1.39).	[5]	2	3
Q.2(b)	Explain the following surface reaction models: (1) Single site, (2) Eley-Rideal.	[5]	2	1
Q.3(a)	Briefly describe progressive-conversion model (PCM) and shrinking unreacted-core model (SCM) for the noncatalytic reaction of particles with surrounding fluid.	[5]	3	2
Q.3(b)	A feed consisting of: 30% of 50-μm radius particles, 40% of 100-μm radius particles, and, 30% of 200-μm radius particles, is to be fed continuously in a thin layer onto a moving grate crosscurrent to a flow of reactant gas. For the planned operating conditions, the time required for complete conversion is 5, 10, and 20 min for the three sizes of particles. Find the conversion of solids on the grate for a residence time of 8 min in the reactor.	[3]	3	3
Q.3(c)	A batch of solids of uniform size is treated by gas in a uniform environment. Solid is converted to give non-flaking product according to the shrinking model. Conversion is about 7/8 for a reaction time of 1 hr, conversion is complete in two hours. What mechanism is rate controlling?	[2]	3	3
Q.4(a)	A catalyst slab of thickness **L** (width and length >> L) is used to conduct the first order reaction A → B. At 450 K, the thiele modulus for this system is 0.5 and the activation energy for the first order rate constant is 100 KJ/mol. The effective diffusivity of the reactant in the slab can be assumed to be independent of temperature, and external mass transfer resistance can be neglected. What will be the effectiveness factor at 470 K?	[5]	4	3

Q.4(b)	Reactant gas (u_o = 0.3 m/s, v_o = 0.3π m^3/s) passes upward through a 2-m diameter fluidized bed (u_{mf} = 0.03 m/s, ϵ_{mf} = 0.5) containing 7000 kg of catalyst (ρ_s = 2000 kg/m^3). Reaction proceeds as follows:	[5]	4	3

$$A \rightarrow R, \qquad -r'''_A = k'''C_A \qquad \text{with } k''' = 0.8\ m^3/(m^3 solid.s)$$

(a) Calculate the conversion of reactant.
(b) If gas were made to flow downward through the solids, we would have a packed bed. Assuming plug flow of gas find the conversion of reactant for this situation.
Given: C_{AO} = 100 mol/m^3, D = 20 X 10^{-6} m^2/s, α = 0.33, d_b = 0.32 m, K_{bc}=0.614 s^{-1}, K_{ce} = 0.133 s^{-1}, f_b = 0.001, f_c = 0.047.

Q.5(a)	Gaseous **A** absorbs and reacts with **B** in liquid according to	[5]	5	3

$$\mathbf{A}\ (g \rightarrow l) + \mathbf{B}(l) \rightarrow \mathbf{R}(l), \quad -r_A = kC_AC_B$$

In a reactor under conditions where, $k_{Ag}a$=0.1 mol/(hr.m^2 of reactor.Pa); $k_{Al}a$=100 m^3 liquid/(m^3 reactor.hr); a = 100 m^2/m^3 reactor; f_l = 0.01 m^3liquid/m^3 reactor; D_{Al} = D_{Bl} =10^{-6} m^2/hr; k = 10 m^3 liquid/(mol.hr); H_A = 10^5 Pa.m^3 liquid/mol.
At a point in the reactor where p_A = 100 Pa and C_B = 100 mol/m^3 liquid,
(a) calculate the rate of reaction in mol/(hr.m^3) of reactor.
(b) describe the following characteristics of the kinetics:
location of the major resistance (gas film, liquid film, main body of liquid);
behavior in the liquid film (pseudo first-order reaction, instantaneous, second-order reaction, physical transport).

Q.5(b)	In slurry reactors (G/L/S), pure reactant gas is bubbled through liquid containing suspended catalyst particles. Let us view this kinetics in terms of film theory. Thus, to reach the surface of the solid, the reactant which enters the liquid must diffuse through the liquid film into the main body of liquid, and then through the film surrounding the catalyst particle. At the surface of the particle, the reactant reacts according to first-order kinetics. Derive an expression for the rate of reaction in terms of these resistances.	[5]	5	3

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