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

CLASS: BE **SEMESTER : VI**
BRANCH: CHEMICAL ENGG. **SESSION : SP/19**

SUBJECT: CL6009 ADVANCES IN REACTION ENGINEERING
TIME: 3.00 Hrs. **FULL MARKS: 60**

INSTRUCTIONS:
1. The question paper contains 7 questions each of 12 marks and total 84 marks.
2. Candidates may attempt any 5 questions maximum of 60 marks.
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) Discuss the non-isothermal multiple chemical reactions in CSTR reactors. [4]

Q.1(b) The elementary liquid-phase reactions [8]

$$A \overset{k_1}{\rightarrow} B \overset{k_2}{\rightarrow} C$$

take place in a 10-liter CSTR. What are the effluent concentrations for a volumetric feed rate of 10 liter /min at a concentration of A of 0.3 mol/liter? The inlet temperature is 283 K.

Additional data:

$C_{PA} = C_{PB} = C_{PC}$ = 200 J/mol.K

k_1 = 3.03 min^{-1} at 300 K, with E_1 = 9900 cal/mol; k_2 = 4.58 min^{-1} at 500 K, with E_2 = 27000 cal/mol

ΔH_{RX1A} = -55000 J/mol A; UA = 40000 J/min-K with $T_a = 57^0C$; ΔH_{RX2B} = -71500 J/mol B

Q.2(a) Discuss the catalyst deactivation by “Poisoning”. [6]

Q.2(b) Discuss and derive the expression for Langmuir adsorption isotherm. [6]

Q.3(a) Describe the Mercury-penetration method for pore volume distribution. [6]

Q.3(b) Brunauer-EmmeU-Teller (BET) adsorption isotherms linearized data are given for N_2 (-195.8 °C) for 0.606 gm of silica gel. [6]

	Intercept (cm^{-3})	Slope (cm^{-3})	Liquid density (g/cm^3)
N_2	0.0001	0.0130	0.808

In BET plot, Y-axis is $P/V(P_o-P)$ and X-axis is P/P_o.
Estimate the area of the silica gel in square meters per gram.

Q.4(a) Discuss all seven factors to be considered in selecting a contactor for fluid-fluid reactor design. [6]

Q.4(b) At high pressure CO_2 is absorbed into a solution of NaOH in a packed column. The reaction is as follows: [6]

$$\underset{(A)}{\underline{CO_2}} + \underset{(B)}{\underline{2NaOH}} \rightarrow Na_2CO_3 + H_2O \text{ with } -r_{Al} = kC_AC_B$$

Find the rate of absorption, the controlling resistance, and what is happening in the liquid film, at a point in the column where $P_A = 10^5$ Pa and C_B = 500 mol/m^3.

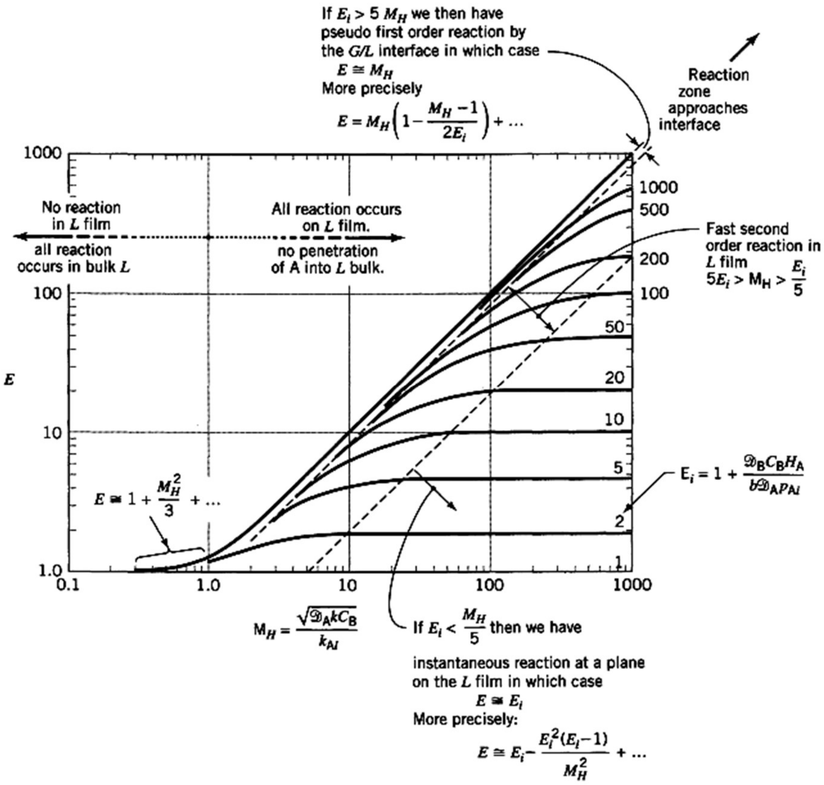
Data: $k_{Ag}a = 10^{-4}\ mol/m^2 \cdot s \cdot Pa$ $H_A = 25\,000\ Pa \cdot m^3/mol$

$k_{Al} = 1 \times 10^{-4}\ m/s$ $\mathscr{D}_A = 1.8 \times 10^{-9}\ m^2/s$

$a = 100\ m^{-1}$ $\mathscr{D}_B = 3.06 \times 10^{-9}\ m^2/s$

$k = 10\ m^3/mol \cdot s$ $f_l = 0.1$

PTO



Q.5(a) In slurry reactors, pure reactant gas (A) is bubbled through liquid (B) containing suspended catalyst particles. Let us view this kinetics in terms of the film theory. To reach the surface of the solid, the reactant first pass through the gas film, and then 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, reactant yields product according to first-order kinetics. Derive an expression for the rate of reaction in terms of these resistances. [6]

$$A\ (g \rightarrow l) + B\ (l) \text{ -----> Products}$$

$$-r_A^{'''} = k_A^{'''} C_A C_B;\ \text{where } -r_A^{'''} \text{ is defined as (mol A)/(m}^3\text{ catalyst. S)}$$

Q.5(b) Dilute aqueous ethanol (about 2-3%) is oxidized to acetic acid by the action of pure oxygen at 10 atm in a trickle bed reactor packed with palladium-alumina catalyst pellets and kept at 30°C. The reaction proceeds as follows: [6]

$$\underset{(A)}{O_2}\ (g \rightarrow l) + \underset{(B)}{CH_3CH_2OH}\ (l) \rightarrow CH_3COOH\ (l) + H_2O$$

with rate

$$-r_A^{'} = k^{'} C_A \text{ with } k' = 1.77 \times 10^{-5}\ \text{m}^3/\text{kg.s}$$

Find the fractional conversion of ethanol to acetic acid if gas and liquid are fed to the top of a reactor. Given:

Gas stream: $V_g = 0.01$ m³/s, $H_A = 86000$ Pa.m³/mol
Liquid stream: $V_l = 2 \times 10^{-4}$ m³/s, $C_{Bo} = 400$ mol/m³
Reactor: 5 m high, 0.1 m² cross section, $f_s = 0.58$
Catalyst: $d_P = 5$ mm, $\rho_s = 1800$ kg/m³, $D_e = 4.16 \times 10^{-10}$ m³/m cat.s
Kinetics: $k_{Ag}a_i = 3 \times 10^{-4}$ mol/m³.Pa. s, $k_{Al}a_i = 0.02$ s⁻¹
$k_{Ac}a_c = 0.0269$ s⁻¹

PTO

Q.6(a) Write the assumptions of Kunni-Levenspiel (K-L) model for bubbling fluidized bed. [4]

Q.6(b) Reactant gas (u_o = 0.3 m/s, V_o = 0.3 π 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: [8]

$$A \rightarrow R, \qquad -r_A''' = k'''C_A \qquad k''' = 0.8\ \frac{m^3}{m^3 s.s}$$

(a) Calculate the conversion of reactant.

(b) If gas were made to flow downward we would have a packed bed. Assuming plug flow of gas find the conversion of reactant for this situation

(c) A suggestion for raising the conversion is to use more solids. So, keeping everything same, find the conversion of reactant if we use 14000 kg of catalyst.

Additional data:

C_{Ao} = 100 mol/m^3, D = 20 X 10^{-6} m^2/s, α = 0.33, Bubble size in the bed 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.7(a) Differentiate between mathematical functions and functionals. [2]

Q.7(b) Starting with classical one-dimensional wave equation, derive the time independent Schrodinger wave equation in one dimension. [4]

Q.7(c) What is design of experiments? Describe the 2^2 full factorial designs with the help of a clear diagram. [6]

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