CATALYTIC REACTOR DESIGN
(CHEN 4281)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) In terms of transition state theory, the catalyst
(a) reduces the potential energy barrier over which the reactants must pass to form products
(b) increases the potential energy barrier over which the reactants must pass to form products
(c) has no effect on the potential energy barrier over which the reactants must pass to form products
(d) none of the above.

(ii) In homogeneous liquid phase catalytic reaction, the observed rate constant will
(a) vary with change in catalyst concentration
(b) not vary with change in catalyst concentration
(c) be an intrinsic constant
(d) none of the above

(iii) The yield coefficient of cell growth ($Y_{A/C}$) is
(a) constant during exponential phase of growth
(b) constant during stationary phase of growth
(c) the slope of C_C versus C_A line
(d) the slope of C_A versus C_A line

(iv) The fractional volume change of the system between no conversion and complete conversion for the isothermal gas phase reaction, $A \rightarrow 3B$ with 50% A and 50% inert initially present is
(a) 2 (b) 1
(c) 0.5 (d) 0

(v) For reaction under pore diffusion regime, the reaction rate
(a) varies directly with catalyst particle size
(b) varies inversely with catalyst particle size
(c) is independent of catalyst particle size
(d) none of the above

(vi) The plot of rate versus substrate concentration of an enzymatic reaction following Michaelis Menten equation gives
(a) a section of rectangular hyperbola (b) a linear plot
(c) an irregular plot (d) none of the above

(vii) Under strong pore diffusion regime a nth-order reaction behaves like a
(a) (n + 1) order reaction (b) $\frac{(n+1)}{2}$ order reaction
(c) $\left(\frac{n-1}{2}\right)$ order reaction (d) Zero order reaction

(viii) The best combination of reactors to achieve the substrate concentration at the maximum cell growth rate is
(a) MFR followed by PFR (b) PFR followed by MFR
(c) two MFRs in series (d) two PFRs in series

(ix) Fedbatch bioreactor is
(a) an unsteady state reactor (b) a steady state reactor
(c) an isothermal reactor (d) none of the above

(x) The maximum velocity (V_m) in Michaelis-Menten equation:
(a) is an intrinsic kinetic parameter (b) is not an intrinsic kinetic parameter
(c) depends strongly on temperature (d) none of the above

Group – B

2. (a) Derive the integrated form of homogeneous liquid phase catalytic reaction and discuss in details how the two intrinsic kinetics constants can be evaluated from experimental data.

(b) The catalytic gas phase reaction A → 4R is run at 3.2 atm and 117°C in a plug flow reactor which contains 0.01 kg of catalyst and uses a feed consisting of the partially converted product of 20 liters/hr of pure unreacted A. The results are as follows:

Run	1	2	3	4
C_{Ain}, mol/liter	0.100	0.080	0.060	0.040
C_{Aout}, mol/liter	0.084	0.070	0.055	0.038

Find a rate equation to represent this reaction.

5 + 7 = 12

3. (a) Define effectiveness factor (η). Show that under strong pore diffusion regime for a first order reaction, A = R, $(-r_A) = kC_A$ taking place on porous solid catalyst of cylindrical in shape, $\eta = \frac{\tanh mL}{mL}$, where mL = Thiele Modulus.

(b) The following kinetic data on the reaction A → R are obtained in an experimental packed bed reactor using various amounts of catalyst and a fixed feed rate F_{A0}, = 10 kmol/hr.

W, kg cat	1	2	3	4	5	6	7
X_A	0.12	0.20	0.27	0.33	0.37	0.41	0.44

(i) Find the reaction rate at 40% conversion.
(ii) In designing a large packed bed reactor with feed rate F_{A0} = 400 kmol/hr how much catalyst would be needed for 40% conversion.
(iii) How much catalyst would be needed in part (ii) if the reactor employed a very large recycle of product stream?

(1 + 5) + (2 + 2 + 2) = 12

Group – C

4. For a gas phase solid catalysed reaction, A = 4 R, following data are obtained.

C_A, mol/lit	0.039	0.0575	0.075	0.092
$(-r_A') \frac{molA}{hr.kgcatalyst}$	3.4	5.4	7.6	9.5

Directly from these data and without using a rate equation, find the mass of catalyst needed to treat 2000 mol/hr of pure A at 117^0C to 35% conversion given C_{A0} = 0.1 mol/lit.

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5. Sucrose is hydrolyzed in a batch bioreactor in presence of the enzyme Sucrase (E) as follows:

Sucrose (A) → product

With initial concentrations of 1(mM) sucrose and 0.01 (mM) enzyme, the following data are obtained.

C_A, mM	0.84	0.68	0.53	0.38	0.27	0.16	0.09	0.04
$(-r_A)$, mM/hr	0.160	0.154	0.152	0.127	0.110	0.0882	0.0625	0.0400

Using Hanse-Woolf method, find the intrinsic kinetic parameters of Michaelis-Menten equation.

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Group – D

6. Five gm sample of a porous solid catalyst is studied N_2 adsorption at – 195.8^0C. The following data are obtained.

Pressure, mmHg	6	25	140	230	285	320	430	505
Volume adsorbed at ^0C, 1 atm,cm^3	61	127	170	197	215	230	277	330

The vapour pressure of N_2 at – 195.8^{0}C is 1 atm. Estimate the surface area in m^2/gm of the sample.

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7. (a) Discuss in details how pore volume distribution of solid catalyst is determined.

   (b) Discuss in detail different methods used for catalyst preparation.

6 + 6 = 12

Group – E

8. A strain of mold was grown in a batch culture on glucose and the following data were obtained:

Time (h)	0	9	16	23	30	34	36	40
Cell concentration (g/l)	1.25	2.45	5.1	10.5	22	33	37.5	41
Glucose concentration (g/l)	100	97	90.4	76.9	48.1	20.6	9.38	0.63

Show that the system follows Monods substrate uninhibited equation.

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9. A fermentation industry wishes to produce a valuable biochemical by maintaining maximum rate of cell growth condition as far as possible. Starting with 15.5 mg / dm^3 of cells and 150 mg / dm^3 of substrate, the fermentation was carried out. The yield of cell was found to be 0.65 mg cell / mg substrate. The cell growth rate was reported to be $R_C = 1.2\ C_AC_C / (C_A + 2)$ mg cells formed / hr. dm^3, where C_A and C_C are substrate and cell concentrations respectively. Find the maximum rate of cell growth that can be achieved at this condition after deducting the necessary equation.

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Department & Section	Submission Link
BT	https://classroom.google.com/c/Mjg3NDMzNTk5ODI1/sa/MzU4OTU1MzEzOTE2/details