B.TECH/ BT /8TH SEM/ CHEN 4281/2018

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 autocalytic reaction the rate follows
(a) section of a rectangular hyperbola
(b) a linear pattern
(c) a parabola
(d) none of the above

(ii) 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.

(iii) 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) $\frac{(n-1)}{2}$ order reaction (d) Zero order reaction

(iv) 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.

(v) The Briggs- Halden theory is based on the assumption that is used in
(a)homogeneous catalysis
(b)heterogeneous catalysis
(c) both homogeneous and heterogeneous catalysis
(d) none of the above

(vi) In homogeneous catalytic reaction the rate
(a) is independent of catalyst concentration
(b) is directly proportional to catalyst concentration
(c) is inversely proportional to catalyst concentration
(d) none of the above.

(vii) The physical or crystalline structure of a solid
(a) imparts catalytic activity to a material
(b) has no bearing with catalytic activity to a material
(c) is responsible for increasing activation energy
(d) none of the above.

(viii) 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

(ix) The slope of of Lineweaver and Burk plot is equal to
(a) 1/Vm (b) -1 / Km (c) – Km (d) Km / Vm

(x) 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

Group – B

2. (a) The catalytic reaction
$A \rightarrow 4R$
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.

(b) Discuss briefly how an integral reactor can be used to determine rate equation of a heterogeneous catalytic reaction using differential method of analysis.

7 +5 = 12

3. (a) Derive a relation between effectiveness factor and Thiele modulus for a first order solid catalyzed gas reaction taking place in presence of a cylindrical pore catalyst under strong pore diffusion regime.

(b) Show that an n^{th} order heterogeneous reaction will behave as $\frac{n+1}{2}th.$ order under strong pore diffusion control regime

7 + 5 = 12

Group – C

4. At 700^0C the rate of decomposition $A \rightarrow 3R$, on a specific catalyst of given size is found to be

$$-r_A = -\frac{1}{w}\frac{dN}{dt} = 10\left(\frac{liter}{gmcat.\,h}\right)C_A$$

A pilot plant is to be built. This is to be a tubular packed bed, 2 cm ID, using 25% of these active catalyst pellets evenly mixed with 75% inert pellets to insure isothermal operations. For 400 mol / hr feed, consisting of 50% A and 50% inert gas at 8 atm and 700^0C, what must be the length of reactor so that $p_{Aout}/p_{Ain} = 0.111$?

Data: catalyst and inert pellets are porous, of diameter d_p = 3 mm, particle density = 2 gm/cm³. Bulk voidage of packed bed = 50%

12

5. The rate of urea conversion as a function of urea concentration in presence of enzyme urease is given below. Find the rate equation using Hanse – Woolf method.

Concentration of urea (C_{urea}), kmol/m³	0.2	0.02	0.01	0.005	0.002
Rate of urea conversion ($-r_{urea}$), kmol/m³-s	1.08	0.55	0.38	0.20	0.09

12

Group – D

6. Study was made on adsorption of N_2 at – 195.8^0C on 5 gm sample of a porous solid catalyst. The following data are obtained.

Pressure, mm Hg	6	25	140	230	285	320	430	505
Volume adsorbed at ⁰C, 1 atm, cm³	61	127	170	197	215	230	277	330

The vapour pressure of N_2 at – 195.8^0C is 1 atm. Estimate the surface area in m²/gm of the sample

12

7. Discuss in detail how Brunauer, Emmett and Teller (BET) method can be applied to find out surface area of catalyst.

12

Group – E

8. (a) 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 / dm³ of cells and 150 mg / dm³ 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

$r_c = 1.2\, C_A C_C / (C_A + 2)$ mg cells formed / hr. dm³

Find the maximum rate of cell growth that can be achieved at this condition.

(b) 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

Find the cell growth rate equation in gm cell formed/h-l

5 + 7 = 12

9. (a) Derive the performance equation of a mixed flow reactor in terms of cell concentration and space time used for carrying out a microbial fermentation reaction following Monod equation and find the condition of wash out.

(b) A fermentation reaction having the following rate equation

$R_c = \frac{1.2C_AC_C}{C_A+2}$, C_A = gm substrate/m³ and $Y_{C/A}$ = 0.1 gm cell/gm substrate

is carried out in mixed flow reactor of volume 5m³. Find the outlet concentration of cells produced for optimum operation when 1 m³/h of substrate solution (C_{A0} = 6 gm/m³) is fed to the reactor.

5 + 7 = 12