B.TECH / CHE /7TH SEM/ CHEN 4141/2017
REACTOR DESIGN
(CHEN 4141)

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

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and <u>any 5 (five)</u> from Group B to E, taking <u>at least one</u> 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) The volume expansion factor of A for the isothermal gas phase reaction, $A \rightarrow 3B$, in presence of 50% A and 0% inert is
(a) 0.5 (b) 1 (c) 2 (d) 3.

(ii) For a homogeneous reaction of nth order, the dimension of the rate constant is given by
(a) l/(time)n (b) $(\text{concentration})^{1-n}$/ (time)
(c) $(\text{concentration})^{n-1}$/ (time) (d) none of these.

(iii) What is the dispersion number for a CSTR?
(a) 0 (b) 1 (c) <1 (d) ∞.

(iv) For a mixed flow reactor operating at steady state, the rate of reaction $(-r_A)$ is equal to
(a) $\frac{F_{A0}}{V}-\frac{dC_A}{dt}$ (b) $\frac{F_{A0}}{V}+\frac{dC_A}{dt}$ (c) $\frac{F_{A0}}{V}\cdot X_A$ (d) $-\frac{dC_A}{dt}$.

(v) An autothermal reactor is
(a) most suitable for a second order reaction
(b) most suitable for a reversible reaction
(c) completely self-supporting in its thermal energy requirements
(d) isothermal in nature.

(vi) 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.

(vii) The Damkohler number is given by
(a) rate of reaction of a reactant/rate of diffusion of reactant to catalyst surface
(b) rate of reaction of a reactant /rate of convective transport of a reactant at the reactor entrance
(c) rate of convective transport of a reactant / rate of reaction of a reactant
(d) rate of diffusion of a reactant/rate of convection.

(viii) The Michaelis – Menten 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.

(ix) If the slope of the heat removal line is greater than the greatest slope of the heat generation curve there will be
(a) only one intersection of the heat removal line and the heat generation curve
(b) two intersections of the heat removal line and the heat generation curve
(c) no intersection of the heat removal line and the heat generation curve
(d) multiple intersections (more than two) of the heat removal line and the heat generation curve.

(x) A consecutive reaction, $A \rightarrow B \rightarrow C$, is characterized by
(a) maxima in the concentration of A
(b) maxima in the concentration of B
(c) maxima in the concentration of C
(d) high exothermicity.

Group - B

2 (a) The reaction $A \rightarrow B$, $r = kC_A$ occurs in a n equal volume CSTRs in series each with residence time τ , with 90% overall conversion. If $k = 0.5\ min^{-1}$, $C_{A0} = 2$ moles/ liter and v = 4 liter / min, what residence times and reactor volumes will be required for n = 1, 2, and 3?

(b) 1 liter/min of liquid containing A and B ($C_{A0} = 0.10$ mol / liter, $C_{B0} = 0.01$ mol / liter) flow into a mixed reactor of volume (V =1 lit). The materials react in a complex manner for which the stoichiometry is unknown. The outlet stream from the reactor contains A, B, and C ($C_{Af} = 0.02$ mol/liter, $C_{Bf} = 0.03$ mol/liter, $C_{Cf} = 0.04$ mol/liter). Find the rate equation of the reaction.

6 + 6 = 12

3. The elementary irreversible organic liquid-phase reaction is carried out in a flow reactor. An equal molar feed in A and B enters at 27°C, and the volumetric flow rate is 2 dm^3/s.

   i) Calculate the PFR and CSTR volumes necessary to achieve 85% conversion when the reaction is carried out adiabatically.

   ii) What is the maximum inlet temperature at which the boiling point of the liquid (500K) would not be exceeded even after complete conversion?

   Data Given:

   $C_{pA} = C_{pB} = 15\,Cal/mol.K, C_{pC} = 30\,Cal/mol.K$

   $H_A^0(273K) = -20\,Kcal/mol, H_B^0(273K) = -15\,Kcal/mol, H_C^0(273K) = -41\,Kcal/mol$

   $T_R = 273K, C_{A0} = 0.1\,Kmol/dm^3$

   $E = 10{,}000\,Cal/mol; k_1 = 0.01\frac{dm^3}{mol.\sec}\,at\,300K$

   $h = 0.2\,Cal/m^2.Sec.K$

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Group - C

4. A first order, heterogeneous, irreversible reaction is taking place within a catalyst pore which is plated with platinum entirely along the length of the pore as shown in the fig.1. The reactant concentration at the plane of symmetry of the pore is equal to one - tenth the concentration of the pore mouth. The concentration at the pore mouth is 0.001 g mol/dm^3, The pore length (2L) is 2 × 10^{-3} cm, and the diffusion coefficient is 0.1 cm^2/s.

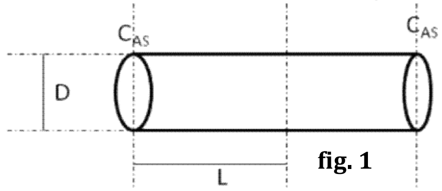

fig. 1

i) Derive an equation for the effectiveness factor

ii) What is the concentration of reactant at L/2?

iii) To what extent should the pore length be reduced if the effectiveness factor is to be 0.8?

iv) If the catalyst support were not plated with platinum, how would you suggest the catalyst support be plated after the pore length L, had been reduced by grinding?

(4 × 3) = 12

5. (a) Explain the catalyst activity and selectivity.

(b) The formation of butyl acetate was conducted in a batch reactor at 100°C, with H_2SO_4 as a homogeneous calatyst. The original feed contained 4.97 moles butanol/mole acetic acid, and the catalyst concentration was 0.032% by weight H_2SO_4. Following rate equation was found to correlate the data when an excess of butanol was used:

$r_A = -kC_A^2$, where C_A is con. of acetic acid g mol/ml, r_A is the rate of reaction in g moles per mililiter per minute. The density of the reaction mixture was assumed constant and equal to 0.75 g/cm^3.

Data given:

k =17.4 cm^3/g (mol) (min)

Density of acetic acid =0.958 g/cm^3

Density of butanol=0.724 g/cm^3

Density of butyl acetate= 0.796 g/cm^3

Calculate time required to obtain a conversion of 50%, where initial concentration of acetic acid is 0.0018 g.mol/cm^3.

3 + 9 = 12

Group - D

6. (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) Deduce the performance equation of fluidized bed reactor using bubble bed model.

7 + 5 = 12

7. In a laboratory packed bed reactor (L_m = 10 cm and u_0 = 2 cm/s) conversion is 97% for the first order reaction A → R.

What would be the conversion in a larger fluidized bed pilot plant (L_m = 100 cm and u_0 = 20 cm/s) in which the estimated bubble size is 8 cm?

Data: u_{mf} = 3.2 cm/s, $\varepsilon_{mf} = \varepsilon_m = 0.5$, D = D_e = 0.204 cm^2/s, $\alpha = 0.34$.

(Subscript m refers to the fixed bed or settled bed condition.)

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Group - E

8. (a) E.coli lives and grows on mannitol with the following kinetics:

$r_C = 1.2\ C_A\ C_C\ /(\ C_A + 2)$ gm cell formed /hr. m^3 with $Y_{C/A} = 0.1$ gm cell/gm mannitol

It is desired to produce 1 Kg cell / day in a batch fermenter. We start with 1000 gm mannitol / m^3 and 0.1 gm /m^3 cells and continue the fermentation until the substrate drops to 10 gm / m^3. The plant operates day and night and the times for filling cleaning and emptying the reactor are 0.23 hours, find the volume of the fermenter needed. C_A and C_C are the concentrations of substrate and cells in gm / m^3 respectively.

(b) Find the equilibrium constant at 500^{0}C for the following elementary reversible reaction.

$A \rightleftharpoons R$

Data: $C_{A0} = 1$ mole / liter, $C_{R0} = 0$, $K_{298K} = 300$, ΔH_r at 298 K = - 18000 cal / mole.

7 + 5 = 12

9. Reagent A undergoes an essentially irrerversible isomerization reaction that obeys first order kinetics

$A \rightarrow B$

Both A and B are liquids at room temperature. Determine the reactor volume necessary to produce 1 million Kg of B in 7000 hr of operation if the batch reactor operates adiabatically.

Data: Rate constant (k) at 163^{0}C = 0.8 hr^{-1}

Activation energy = 28960 cal / mol

Molecular weight of A = 250

Heat of reaction = - 83 cal / gm

Liquid heat capacity = 0.5 cal/gm. ^{0}C

Liquid density = 0.9 gm/cm^3

The times necessary to fill and drain the reactor may be assumed to be equal to 10 and 12 minutes respectively. It may be assumed that negligible reaction occurs during the 14 minutes it takes to heat the feed from its inlet temperature to 163^{0}C. The desired conversion of A is 97%.

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