CHEMICAL REACTION ENGINEERING I
(CHE2204)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

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

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) Order of a chemical reaction
(a) Can have fractional value (b) Must be an integer
(c) Only apply to a non-elementary reaction (d) None of the above

(ii) The half life period of a first order reaction is given by (where, K = rate constant.
(a) 1.5K (b) 2.5K (c) 0.693K (d) 6.93K

(iii) The fractional volume change of the system between no conversion and complete conversionfor the isothermal gas phase reaction, A ->3B with 50% A and 50% inert initially present is?
(a) 0 (b) 1 (c) 2 (d) 1.5

(iv) In a chemical reaction, the time required to reduce the concentration of reactantfrom 100 mol/lit to 50 mol/lit is same as that required to reduce it from 2mol/lit to 1 mol/lit in the same volume. Then the order of this reaction is
(a) 0 (b) 2 (c) 1 (d) None of the above

(v) The space time and residence time are same for
(a) Constant volume system (b) Variable volume system
(c) Either constant or variable volume system (d) None of the above

(vi) For a reaction having order (n) greater than unity, the best combination of reactors will be
(a) PFR, small mixed, large mixed (b) Large mixed, small mixed, PFR
(c) Small mixed, large mixed, PFR (d) Small mixed, PFR, large mixed

(vii) For the following first order reaction

$$A \xrightarrow{k_1 = 5s^{-1}} R \xrightarrow{k_2 = 0.7s^{-1}} S$$

Time required for R to reach at its maximum concentration
(a) 2.3 s (b) 0.33 s (c) 3.02 s (d) 0.46 s

(viii) Selectivity in parallel reactions is defined as the ratio of__
(a) Moles of desired product formed to the moles of undesired material formed
(b) Moles of undesired product formed to the moles of desired material formed
(c) Moles of product formed to the moles of reactant consumed
(d) Moles of reactant consumed to the moles of product formed

(ix) The expression for mean conversion for a first order reaction in an ideal CSTR using the segregation model is
(a) $\overline{X} = \frac{1+k\tau}{k\tau}$ (b) $\overline{X} = \frac{k\tau}{1+k\tau}$ (c) $\overline{X} = k\tau$ (d) $\overline{X} = \frac{1}{k\tau}$

(x) Vessel dispersion number in an ideal CSTR is
(a) 0 (b) 1 (c) 10 (d) ∞

Fill in the blanks with the correct word

(xi) A chemical reaction is of zero order, when the reaction rate is _____.

(xii) For a _____ order chemical reaction, the half-life period is independent of the initial concentration ofthe reactant.

(xiii) The performance equations for constant density systems are identical for _____.

(xiv) The desired combination of a PFR and a MFR to maximize production from a first order reaction is _____.

(xv) The example of a zero parameter model is _____.

Group - B

2. (a) Distinguish between Integral and Differential method of analysis of rate equations. *[(CO1)(Apply/IOCQ)]*

(b) Milk is pasteurized if it is heated to 63^0C for 30 min, but if it is heated to 74°C it only needs 15 s for the same result. Find the activation energy of this sterilization process. *[(CO1)(Apply/IOCQ)]*

(c) Liquid A decomposes by first-order kinetics, and in a batch reactor 50% of A is converted in a 5-minute run. How much longer would it take to reach 75% conversion? *[(CO1)(Apply/IOCQ)]*

3 + 4 + 5 = 12

3. (a) A gas feed enters a reactor at 720 K and 1.2 atm with C_{A0} = 100, C_{B0} = 150, C_{R0} = 50 and C_{i0} =100 where i stands for an inert material. In the reactor the reaction is as follows.

$$A + 3B \rightarrow 2R$$

The exit gas passes through a cooler and leaves the system at 300K and 1 atm. Find the fractional conversion of A (X_A) and concentration of B (C_B) in the cool exit stream. Assume ideal gas behaviour. *[(CO1)(Apply/HOCQ)]*

(b) Find the first order rate constant for the disappearance of A in the gas reaction $2A \rightarrow R$ if on holding the pressure constant the volume of the reaction mixture, starting with 80% A decreases by 20% in 3 min. *[(CO1)(Apply/HOCQ)]*

8 + 4 = 12

Group - C

4. A daily production of 50 tonnes of ethyl acetate from alcohol and acetic acid is required. The reaction proceeds according to

$$C_2H_5OH\ (A) + CH_3COOH\ (B) \leftrightarrow CH_3COOC_2H_5\ (P) + H_2O\ (Q)$$

The reaction rate in the liquid phase at 100^0C is $(-r_A) = k(C_AC_B - C_PC_Q / K)$, where,k = 7.93 x 10^6 m^3/ kmol.s and K = 2.93. The feed solution contains 23 wt% of acid, 46 wt% of alcohol and no ester. The required conversion of acid is 35%. The density may be assumed to have a constant value 1020 kg / m^3. The plant must be operated day and night and times for filling, emptying and cleaning operation of a reactor is1 hour. What would be the required reactor volume if one batch reactor vessel is used? *[(CO2)(Apply/HOCQ)]*

12

5. (a) At present Aqueous reactant A is 50% converted in a mixed flow reactor. Keeping the feedcomposition and feed rate unchanged we plan to replace our present reactor with one 4 times the size. What will be the new conversion if the reaction is first order ($-r_A = kC_A$)? *[(CO3)(Apply/HOCQ)]*

(b) A homogeneous gas reaction $A \longrightarrow 3R$ has a reported rate at 215^0C-$r_A = 10^{-2}C_A^{0.5}$ mol/liter.sec
Find the space time needed for 80% conversion of a 50% A and 50% inert feed to a plug flow reactor operating at 215^0C and 5 atm. *[(CO3)(Apply/HOCQ)]*

7 + 5 = 12

Group - D

6. Under appropriate conditions A decomposes as follows.

$$A \xrightarrow{k_1} R \xrightarrow{k_2} S \qquad k_1 = k_2 = 0.1 min^{-1}$$

R is to be produced from 1000 litre/hr of feed in which C_{A0} = 1 mol/liter, C_{R0}= 0, C_{S0}, = 0

(i) What size plug flow reactor will maximize the yield of R and what is the concentration of R in theeffluent stream from this reactor?

(ii) What size mixed flow reactor will maximize the yield of R and what is the concentration of R inthe effluent stream from this reactor? *[(CO4)(Analyse/HOCQ)]*

(6 + 6) = 12

7. When aqueous A and aqueous B ($C_{A0} = C_{B0}$) are brought together, they react in two ways:

$$A + B \rightarrow R + T,\ r_R = 50C_A\ mol/m^3h$$

$$A + B \rightarrow S + U,\ r_S = 100C_B\ mol/m^3h$$

With $C_{total} = C_{A0} + C_{B0}$ = 60 mol/m^3, find the size of mixed flow reactor needed and the R/S ratioproduced for 90% conversion of a feed with flow rate of 300 mol A/hr.

[(CO4)(Apply/IOCQ)]

12

Group - E

8. (a) Dispersed noncoalescing droplets (C_{A0}=2 mol/litre) react ($A \rightarrow R, -r_A = kC_A^2$, k=0.5 litre/mol.min) as they pass through a contactor. Find the average concentration of A remaining in the droplets leaving the reactor if the RTD value is 0.5 in the time interval between 1 min to 3 min. *[(CO6)(Analyse/IOCQ)]*

(b) A reactor is used for decomposing liquid with the following rate equation

$-r_A = kC_A$, k=0.307 min^{-1}

Find the fraction of reactant unconverted in the reactor assuming segregation model holds good and compare with the fraction unconverted in a PFR of same size for mean residence time 15 min. Given the RTD data: *[(CO6)(Apply/HOCQ)]*

t	E
5	0.03
10	0.05
15	0.05
20	0.04
25	0.02
30	0.01

6 + 6 = 12

9. (a) For a first order liquid phase irreversible reaction with a specific reaction rate 0.1 min^{-1} at 320 K in a completely segregated fluid, calculate the mean conversion given the RTD data below. (use graph) *[(CO6)(Analyse/HOCQ)]*

t, min	E(t), min^{-1}
0	0
1	0.02
2	0.1
3	0.16
4	0.2
5	0.16
6	0.12
7	0.8
8	0.06
9	0.044
10	0.03
12	0.012
14	0

(b) Consider a second order reaction carried out in a real CSTR which can be modelled as an ideal CSTR followed by an ideal PFR. If the residence time in the CSTR and PFR are $\tau_s = \tau_p$ = 1 min, the reaction rate constant is 1 m^3/kmol. min, and C_{A0}= 1kmol/m^3, find the conversion in the real reactor. *[(CO6)(Apply/IOCQ)]*

7 + 5 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	0	36.46	63.54