CHEMICAL REACTION ENGINEERING-I
(CHEN 3102)

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) For the reaction NO + ½ O_2 = NO_2 carried out in presence of Pt-Rh catalyst, the reaction
(a) is considered as homogeneous
(b) is considered as heterogeneous
(c) may be either homogeneous or heterogeneous
(d) none of the above.

(ii) Pick out the correct statement
(a) A chemical reaction occurs when the energy of the reacting molecule is less than the activation energy of the reaction
(b) Chemical equilibrium is a static state
(c) A photochemical reaction is catalysed by light
(d) Reactions with high activation energies are very temperature sensitive.

(iii) A given reaction is much more temperature sensitive at
(a) low temperature (b) high temperature
(c) all temperature levels (d) none of the above.

(iv) The rate constant of a reaction depends on the:
(a) Time of reaction
(b) Extent of reaction
(c) Initial concentration of reactants
(d) Temperature of the system.

(v) Higher free energy of activation of a chemical reaction (at a given temperature) implies
(a) higher rate of reaction
(b) higher equilibrium conversion
(c) Slower rate of reaction
(d) none of the above.

(vi) The half life period of a first order reaction is given by (where, k = rate constant.
(a) 0.693k (b) 0.693/k
(c) 0.593k (d) 0.593/k.

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

(viii) The performance equations for constant density systems are identical for
(a) PFR and MFR (b) P.F.R. and batch reactor
(c) MFR and batch (d) none of the above.

(ix) A space time of 3 hours for a flow reactor means that
(a) It takes three hours to dump the entire volume of the reactor with feed
(b) Three reactor volumes of feed can be processed every hour ,Conversion is cent per cent after three hours
(c) The time required to process one reactor volume of feed (measured at specified conditions) is 3 Hours
(d) none of the above.

(x) Stimulus-response techniques are commonly used to characterize the extent of non-ideal flow in vessels. Tracer input signal is used as stimulus. Any material can be used
(a) as tracer if it can disturb the flow pattern in the vessel
(b) as tracer if it does not disturb the flow pattern in the vessel and it can be detected
(c) as tracer if it follows ideal flow patterns
(d) none of the above.

Group – B

2. (a) Show that the following scheme

$N_2O_5 \rightleftharpoons NO_2 + NO_3^*$

$NO_3^* \rightarrow NO^* + O_2$

$NO^* + NO_3^* \rightarrow 2\, NO_2$

Is consistent with and can explain the observed first order decomposition of N_2O_5.

(b) At 500 K the rate of a bimolecular reaction is ten times the rate at 400 K. Find the activation energy of this reaction from collision theory.

6 + 6 = 12

3. (a) An aqueous solution of ethyl acetate is to be saponified with sodium hydroxide. The initial concentration of ethyl acetate is 5.0 g/liter and that of caustic soda is 0.10 normal. Values of the second-order rate constant, in liters/(g mole)(min), are k = 23.5 at 0°C and 92.4 at 20^{0}C. The reaction is

essentially irreversible. Estimate the time required to saponify 95% of the ester at 40°C.

(b) Find the first order rate constant for the disappearance of A in the gas reaction 2A = R if on holding the pressure constant the volume of the reaction mixture , starting with 80% A decreases by 20% in 3 min.

8 + 4 = 12

Group – C

4. (a) The gas leaving an ammonia oxidation plant consists of 10% NO, 1% NO_2, 8% O_2 and rest inert. The gas is allowed to oxidize NO (A) + $1/2O_2$ (B) = NO_2 (R) until NO_2: NO ratio reaches 8:1 and the oxidized gas is then absorbed in water to produce nitric acid. Calculate the size of the tubular reactor (assuming plug flow) operating at 20^0C and I atm needed to NO to NO_2 oxidation for a gas feed rate of 1000 m^3/hr (measured at 0^0C and 1 atm). The reaction rate equation is

$$r_{NO_2} = 14000 C_{No}^2 C_{O_2} \frac{kmol}{m^3 s}$$

(b) An aqueous reactant stream (4mol A/lit) passes through a mixed flow reactor followed by a plug flow reactor. Find the concentration at the exit of the plug flow reactor if in the mixed flow reactor $C_{A=}$ 1 mol/lit. The reaction is first order with respect to A and the reactor volumes are equal.

7 + 5 = 12

5. (a) The elementary irreversible aqueous-phase reaction $A + B \rightarrow R + S$ is carried out isothermally as follows. Equal volumetric flow rates of two liquid streams are introduced into a 4-liter mixing tank. One stream contains 0.020 mol A/liter, the other 1.400 mol B/liter. The mixed stream is then passed through a 16-liter plug flow reactor. We find that some R is formed in the mixing tank, its concentration being 0.002 mol/liter. Assuming that the mixing tank acts as a mixed flow reactor, find the concentration of R at the exit of the plug flow reactor as well as the fraction of initial A that has been converted in the system.

(b) Show that the performance equation of a recycle reactor changes to that of a mixed flow reactor if the recycle ratio (R) tend to infinity.

6 + 6 = 12

Group – D

6. (a) Substance A in the liquid phase produces R and S by the following reactions

R second order

$A \nearrow \searrow$

S first order

A feed (C_{A0} =1, C_{R0} = 0, C_{S0}, = 0) enters two mixed flow reactors in series, (τ = 2.5 min, τ ,= 10 min). Knowing the composition in the first reactor (C_{A1} = 0.4, C_{R1} = 0.2, C_{S1} = 0.7), find the composition leaving the second reactor.

(b) A and B react with each other as follows:

$2A \rightarrow R, \quad r_R = k_1C_A^2$

$A + B \rightarrow S, \; r_S = k_2C_AC_B$

$2B \rightarrow T, \quad r_T = k_3C_B^2$

What ratio of A and B should be maintained in a mixed flow reactor so as to maximize the fractional yield of desired product S?

6 + 6 = 12

7. Chemical R is to be produced by the decomposition of A in a given mixed reactor. The reaction proceeds as follows:

$$A \rightarrow R, \quad r_R = k_1C_A$$
$$2A \rightarrow S, \quad r_S = k_2C_A^2$$

Let the molar cost ratio $\$_R/\$_A = M$ (S is waste material of no value), and for convenience let $k_1 = Nk_2C_{A0}$. In the feed C_{A0} is fixed.

(i) Ignoring operating costs, find what conversion of A should be maintained in the reactor to maximize the gross earnings and therefore the profits.

(ii) Repeat part (i) with the hourly operating cost dependent on feed rate and given by $\alpha + \beta F_{A0}$.

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Group – E

8. (a) Define mean residence time ($\bar{t}$) and variance (σ^2) for non ideal reactor system and discuss in detail how these can be determined from tracer experiment.

(b) State the different types of models available for determination of non ideality of reactors and discuss them briefly.

6 + 6 = 12

9. The concentration reading in the following table represents a continuous response to a delta function input into a closed vessel which is used as a chemical reactor.

Time (t), min	0	5	10	15	20	25	30	35
Tracer concentration, gm/L fluid	0	3	5	5	4	2	1	0

The vessel is to be used to carry out a first order liquid phase reaction $A \rightarrow R$ having rate constant (k) = 0.307 min^{-1}. Find the fraction of reactant unconverted in this real reactor.

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Department & Section	Submission Link
CHE	https://classroom.google.com/c/MTQzMjU0NzQ1Nzg1/a/MjcxMTMxODYyOTk0/details