CHEMICAL REACTION ENGINEERING
(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 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) 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) The units of frequency factor in Arrhenius equation
(a) is same as that of the rate constant
(b) is different from the units of the rate constant
(c) is unitless
(d) none of the above.

(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 Decade method is used to simplify the calculations in connection with determination of slope of equation plotted in _____ graph paper
(a) Triangular (b) Log-Log
(c) Semi-log (d) Normal rectangular

(v) The order of a Chemical Reaction cannot be
(a) zero (b) fraction
(c) negative (d) an integer.

(vi) 1 liter / sec of gaseous reactant A is introduced into a mixed flow reactor having volume 4 liters. The stoichiometry is $A \rightarrow 3R$. The conversion is 50%, and under these conditions the residence time is
(a) 1 sec (b) 2 sec (c) ½ sec (d) None of the above.

(vii) 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

(viii) The third moment of RTD refers to
(a) mean residence time (b) variance
(c) skewness (d) space time.

(ix) Reaction Invariants are
(a) constants
(b) state variables which are not affected by reaction
(c) path variables
(d) none of the above.

(x) For Interpretation of Batch Reactor Data the Initial Rate Method of Analysis is a modification of
(a) Integral Method (b) Differential Method
(c) Half Life Method (d) Flooding Method.

Group – B

2. (a) Under the influence of oxidizing agents hypophosphorous acid is transferred into phosphorous acid:

$$H_3PO_2 \rightarrow H_3PO_3$$

The kinetics of this transformation present the following features.
At low concentration of oxidizing agent

$$r_{H3PO3} = k[\text{oxidizing agent}]\,[H_3PO_2]$$

At high concentration of oxidizing agent

$$r_{H3PO3} = k'[H^+]\,[H_3PO_2]$$

To explain the observed kinetics, it has been postulated that with hydrogen ion as catalyst normal unreactive H_3PO_2 is transferred into an active form, the nature of which is unknown. This intermediate then reacts with the oxidizing agent to give $H3PO_3$. Show that this scheme does explain the observed kinetics.

(b) The pyrolysis of ethane proceeds with an active energy of about 300 kJ /mol. How much faster is the decomposition at 650^0C than at 500^0C?

8 + 4 = 12

3. (a) Prove that for a 2nd order irreversible bimolecular reaction, A+2B → Products

$$\ln \frac{M - 2X_A}{M(1 - X_A)} = C_{AO}(M-2)kt$$

where, $M = C_{BO}/C_{AO}$ & M# 2 (Symbols stand for usual notations).

(b) For the reactions in series, $A \xrightarrow{k_1} R \xrightarrow{k_2} S$, $k_1 = k_2$, Find the maximum concentration of R and when it is reached.

6 + 6 = 12

Group – C

4. (a) We are planning to operate a batch reactor to convert A into R. This is a liquid reaction, the stoichiometry is A → R, and the rate of reaction is given in the following table. How long must we react each batch for the concentration to drop from C_A = 1.3 mol /liter to C_{Af} = 0.3 mol / liter?
Data:

C_A mol /liter	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0	1.3
- r_A, mol / liter. min	0.1	0.3	0.5	0.6	0.5	0.25	0.10	0.06	0.05	0.045

(b) A high molecular weight hydrocarbon gas A is fed continuously to a heated high temperature mixed flow reactor where it thermally cracks (homogeneous gas reaction) into lower molecular weight materials, collectively called R, by a stoichiometry approximated by A -5R. By changing the feed rate different extents of cracking are obtained as follows:

F_{A0}, millimol/hr	300	1000	3000	5000
$C_{Aout.}$ Millimol / liter	16	30	50	60

The internal void volume of the reactor is V = 0.1 liter, and at the temperature of the reactor the feed concentration is C_{A0} = 100 millimol/liter. Find a rate equation to represent the cracking reaction.

6 + 6 = 12

5. The homogeneous reaction A = R is be carried out in a flow reactor system has the following rate law,

$$-r_A = \frac{kC_A}{(1+K_AC_A)^2}$$

Where k = 1 min^{-1} and K_A = 1 dm^3/min
The entering concentration of A is 2 mol/dm^3. What type of reactor or combination of reactors would have the smallest volume to achieve 80% conversion? What will be the volume of each reactor if the initial flow rate of A is 200 mol/min.

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Group – D

6. (a) A 20 liter MFR is to treat a reactant which decomposes as follows

$A \rightarrow R$, $r_R = 4hr^{-1}C_A$

$A \rightarrow S$, $r_S = 1hr^{-1}C_A$

Find the feed rate and conversion of reactant so as to maximize profits. What are these on an hourly basis?
*Data;*Feed material A costs $1/mol at C_{A0} = 1 mol/lit, product R sells for $5/mol and s has no value. The total operating cost of reactant and product separation equipment is $25/hr + $1.25/mol A feed to the reactor. Unconverted A is not recycled.

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

$2A \rightarrow R, \quad r_R = k_1 C_A^2$

$A + B \rightarrow S, \quad r_S = k_2 C_A C_B$

$2B \rightarrow T, \quad r_T = k_3 C_B^2$

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. (a) The catalytic reaction

$$A \rightarrow 4R$$

is studied in a plug flow reactor using various amounts of catalyst and 20 liters/hr of pure A feed at 3.2 atm and 117°C. The concentrations of A in the effluent stream are recorded for the various runs as follows.

Run	1	2	3	4
Catalyst used,kg	0.020	0.040	0.080	0.160
C_{Aout}, mol/liter	0.074	0.060	0.044	0.029

Find the rate equation for this reaction.

(b) Prove that for reaction under strong pore diffusion control regime

$$\eta = \frac{\tanh\phi}{\phi}$$

Where η = Effectiveness factor and ϕ = hiele modulus

6 + 6 = 12

Group – E

8. Deduce a suitable RTD zero parameter model of a PFR.

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9. Show for a One parameter Tank-in Series (RTD) model, the variance decreases as the number of tanks increases.

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Department & Section	Submission Link
CHE	https://classroom.google.com/c/MTQzMjU0NzQ1Nzg1/a/MjcxNDQzMjI2ODk1/details