Total No. of Questions : 8] *[Total No. of Printed Pages : 5*

Roll No ....

CM-6004-CBGS

B.E. VI Semester

Examination, June 2020

Choice Based Grading System (CBGS)

Chemical Reaction Engineering-I

Time : Three Hours

Maximum Marks : 70

Note : i) Attempt any five questions. All questions carry equal marks.

ii) All parts of each question are to be attempted at one place.

iii) Assume suitable values for missing data, if any.

1. a) For a zero order reaction $A \rightarrow B$, 80% conversion is obtained in 1 hr. If the initial concentration is 1 $kmol/m^3$, calculate the rate and conversion after 30 minutes of reaction. 3

b) Determine the overall order of the reaction $aA + bB \rightarrow P$. Three batch runs was taken using various C_{A0} = 12, 18, 12, $kmol/m^3$ and C_{B0} = 22, 22, 12 $kmol/m^3$ with initial rate of 0,4, 0.8 and 0.3 $kmol/m^3$ respectively. 5

c) A gas phase reaction $2A \rightarrow B + 3C$ having second order reaction mechanism is carried out in a constant volume batch reactor. Initially pure reactant A is fed to the system at 1.5 atm pressure. It is observed that pressure rises by 45% in 7 min. Calculate the % conversion achieved. If the reaction is carried out in constant pressure reactor, how much time will be required to achieve the same conversion and also calculate the fractional increase in volume? 6

2. a) Calculate ε_A for reaction 2A + 20% Inert $\rightarrow$3R + Inert? 3

   b) A gas phase reaction A$\rightarrow$2R, follows zero order kinetics, is carried out at constant volume with 15% inerts. It is observed that the pressure rises from 1 bar to 1.4 bar in 110 sec. If the reaction is carried out at constant pressure, how much fractional change in volume will be observed in 4 min if the feed contains 30% inerts and is at 3 bar pressure. 5

   c) Every May 22 I plant one watermelon seed. I water it, I fight slugs, I pray, I watch my beauty grow, and finally the day comes when the melon ripens. I then harvest and feast. Of course, some years are sad, like 1980, when a bluejay flew off with the seed. Anyway, six summers were a pure joy and for these I've tabulated the number of growing days versus the mean day time temperature during the growing season. Does the temperature affect the growth rate? If so, represent this by an activation energy. 6

Year	1976	1977	1982	1984	1985	1988
Growing days	87	85	74	78	90	84
Mean temp. °C	22.0	23.4	26.3	24.3	21.1	22.7

3. a) In a train of CSTRs of equal volume, an irreversible, constant density 1st order reaction is carried out. Show that if the number of CSTR is very large, the total volume of all the reactors in chain tends to that of a PFR for same extent of conversion. 3

   b) 1 lit/s of 20% ozone - 80% air mixture a 1.5 atm and 93°C passes through PFR. Under these conditions ozone decomposes by homogeneous reaction

   $2O_3 \rightarrow 3O_2 \quad -r_{ozone} = kC^2_{ozone}$. What size reactor is needed for 50% decomposition of ozone? (k = 0.05 lit/mol.s) 5

c) 100 gmol of R are to be produced hourly from a feed consisting of a saturated solution of A (C_{A0} = 0.1 mol/lit) in a mixed flow reactor with rate constant of 0.2 per hour. Cost of reactant = Rs. 0.5 per mol A. Cost of reactor including installation, auxiliary equipment, instrumentation, overhead, labor, depreciation, etc. = Rs. 0.01 per (hour lit). Determine the conversion for minimum total cost per hour? 6

4\. a) For a non-catalyzed reaction carried out at 40°C, the activation energy is 75 kJ/mol. The activation energy of the same reaction carried out in presence of catalyst is 55 kJ/mol. Determine how much faster the catalyzed reaction than non-catalyzed reaction? 3

b) Liquid reactant A decomposes as per the following reaction scheme:

$A \rightarrow R \quad k_1 = 0.4\ m^3/(mol.min)$

$A \rightarrow S \quad k_2 = 2\ min^{-1}$

An aqueous feed containing A with $C_{A0} = 40\ mol/m^3$ enters a reactor, decomposes and a mixture of A, R and S leaves the reactor. Find the operating condition (X_A, τ and C_R) which maximizes C_R in a mixed flow reactor. 5

c) A product B is to be produced from a reagent A which also reacts to given worthless by products. The instantaneous yield is found to depend on the conversion of A according to $\varphi = 0.6 + 2x - 5x^2$. The reaction will be terminated when $\varphi = 0.4$ as it is uneconomical to continue to higher conversions, which leads to lower yields. Calculate the overall yield if the reaction were carried out in a (i) bath (ii) mixed flow reactor. If the reactions were carried out in two CSTR in series what conversion in the effluent from the first tank would lead to the highest overall yield and what is that overall yield? 6

5. a) Explain the concept of maximization of rectangles for the arrangements of flow reactors. 3

b) We are constructing a 1-liter popcorn popper to be operated in steady flow .First tests in this unit show that 1 liter/min of raw corn feed stream produces 28 liter/min of mixed exit stream. Independent tests show that when raw corn pops its volume goes from 1 to 31. With this information determine what fraction of raw corn is popped in the unit. 5

c) The concentration readings given below represent a continuous response to a pulse input into a closed vessel.

Time (min)	0	5	10	15	20	25	30	35
C(g/lit))	0	3	5	5	4	2	1	0

This vessel is to be used as a reactor for decomposition of a liquid A with rate constant of 0.307 min^{-1}. Estimate the fraction of reactant unconverted in the real reactor using segregation model. 6

6. a) At present, conversion is 66.67% for the elementary second order liquid reaction $2A \rightarrow 2R$ when operating in an isothermal PFR with recycle ration of unity. Determine the conversion if the recycle stream is shut off. 3

b) An aqueous reactant stream (4 mol A/lit) passes through a MFR followed by a PFR. Find the concentration at the exit of the PFR if in the MFR C_A = 1 mol/lit. The reaction is 2^{nd} order with respect to A, and the volume of the PFR is three times that of the MFR. 5

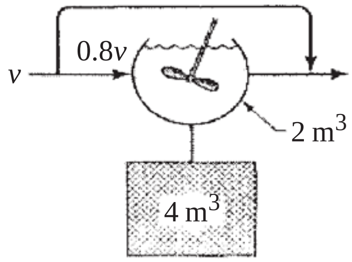
c) Show that for a 1^{st} order, constant density reaction carried out in two CSTRs in series, minimum total volume is required when the two MFRs are equal in size. 6

7. a) Draw schematics to show the non-ideal flow patterns which may exist in process equipments. 3

b) What do you mean by axial dispersion? Write the significance of dispersion coefficient. Also discuss the extent of dispersion number for PFR and MFR. 5

c) The second order aqueous reaction $A + B \rightarrow R + S$ is run in a large tank reactor ($V = 6\ m^3$) and for an equimolar feed stream conversion of reactants is 60%. Unfortunately, agitation in our reactor is rather inadequate and tracer tests of the flow within the reactor give the flow model sketched in Fig. What size of mixed flow reactor will equal the performance of our present unit? 6

(Assume $C_{A0} = C_{B0} = 100$ and $\nu = 100\ m^3/hr$)



8. a) Liquid reactant A decomposes to R and S as in a parallel reactions. $r_R = 0.4C_A^2$ and $r_s = 2C_A$ (mol/min.m^3). Find the maximum possible concentration of R in MFR. 3

b) What restrictions of temperature should be placed on the reactor operating isothermally for $A \Leftrightarrow B$ if we are to obtain an equilibrium conversion of 75% or higher? (Temperature range = 0 to 100°C) $\Delta G^\circ_{298K} = -14130$ J/mol $\Delta H^\circ_{298K} = -75300$ J/mol, $C_{P_A} = C_{P_B}$ = constant. 5

c) What is optimum temperature progression? How it is useful for the design of PFR and MFR? 6

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