Ref. No.: Ex/ChE/T/312/2019

B.E. CHEMICAL ENGINEERING THIRD YEAR FIRST SEMESTER EXAM 2019
CHEMICAL REACTION ENGINEERING- I

Time: Three Hours | Full Marks: 100

Use a separate Answer-Script for each part

Part - I

Answer Question No.1 and any *two* from the rest

All the terms have their usual significance

1. (i) Derive the design equation of a recycle reactor and indicate the condition to assume ideal PFR or CSTR mode. **[7]**

1.(ii) Using characteristic rate- conversion plot of autocatalytic reaction, elucidate graphically the selection of most suitable reactor type for achieving low, intermediate and high conversion levels. **[3]**

1. (iii) It is desired to treat 10 L/min of liquid feed containing 1 mol A /L to 99% conversion. The stoichiometry and kinetics of the reaction are given by

$A \rightarrow R, -r_A = \frac{C_A}{0.2 + C_A}, mol/\min.L$ .Suggest a good arrangement for doing this using two CSTRs and find the size of the two reactors needed. Sketch the final design selected. **[8]**

2.(i) At 650°C phosphine vapour decomposes as follows:

$4PH_3 \rightarrow P_4(g) + 6H_2; -r_{phosphine} = (10\,hr^{-1})C_{phosphine}$ .What size of PFR operating at 649°C and 11.4 atm is needed for 75% conversion of 10 mol/hr of phosphine in a 2/3 phosphine 1/3 inert feed? **[8]**

2.(ii)Consider the autocatalytic reaction $A + R \rightarrow R + R; \; -r_A = 0.001C_AC_R$ mol/L.s. We wish to process 1.5 L/s of a $C_{A0} = 10$ mol/L feed to the highest conversion possible in the reactor system consisting of four 100L MFRs connected as you wish and any feed arrangement. Sketch your recommended design and feed arrangement and determine C_{Af} (concentration of A at the exit of the fourth reactor) from the system. **[8]**

3. (i) Thermal cracking of a high molecular weight hydrocarbon is carried out in a CSTR at high temperature. The products of thermal cracking are lower molecular weight compounds(S) according to A $\rightarrow$4S ; The following data are available:

[Turn over

F_{A_0} ,mmol/h	336	1120	3360	5600
C_A ,mol/m^3	17.92	33.6	56	67.2

The internal void volume of the CSTR is 0.112 L. Entrance feed concentration (C_{A0}) to the reactor is 112 mmol/L (mol/m^3). Determine the rate equation of this reaction.

[8]

3.(ii) Consider a reversible reaction $A+B \rightleftharpoons C+D$ being conducted in an isothermal semibatch reactor wherein B is continuously being fed at a constant rate to a batch of another reactant A. Determine the conversion of A as a function of time. **[8]**

4. (i) Elucidate the method of evaluating the model parameters using a step tracer input for modeling a real CSTR with dead-space and bypassing. **[8]**

4. (ii) A segregated flow situation is said to exist in a Plug Flow Reactor,derive an equation for prediction of mean conversion for a first order homogeneous constant volume reaction. **[8]**

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Part II

Full Marks 50

Answer any two questions. All questions do NOT carry equal marks.

1. In a non-isothermal, non-adiabatic CSTR (of volume V) with a cooling coil, the reaction

$A + B \rightarrow C$ is carried out, which is first order in A. Feed contains an inert M, other than A and B. The cooling coil has heat transfer surface area A, overall heat transfer coefficient U, and constant coolant temp. T_A. Using letter symbols and appropriate notation as necessary, deduce expressions for conversion as a function of temperature separately from the mass and energy balances respectively. Now indicate how you will obtain the operating temperature from these expressions. **[25]**

2. Pure A [C_{A0}=100] is fed to a mixed flow reactor, R and S are formed, and the following outlet concentrations are noted. Find an appropriate kinetic scheme to fit these data.

Run	C_A	C_R	C_S
1.	75	15	10
2.	25	45	30

[20]

3. In a 20 litre MFR, reactant A decomposes by two parallel reactions to give R and S, both first order with rate constants 4 h^{-1} and 1 h^{-1}respectively. Find feed rate and conversion X_A for maximum profit. What is the maximum profit per hour?

Data:

S has no value and unconverted A is NOT recycled. Total operating cost = \$ 25 h^{-1} + \$ 1.25 per mol A fed. Product R sells at \$ 5 per mol, reactant A costs \$ 1 per mol at C_{A0} = 1 mol/litre. **[25]**

4. 1 litre of a mixture contains 45 mol A and 5 mol B. However, the desired molar ratio of A to B is at least 100. To attain this ratio, how much D should be added to the mixture if it reacts with both A and B as follows: (both reactions go to completion)

$A + D \rightarrow R$ [$-r_A = 21\, C_A C_D$]

$B + D \rightarrow S$ [$-r_B = 147\, C_B C_D$] **[20]**