BACHELOR OF CHEMICAL ENGINEERING 3RD Year 1st Semester EXAMINATION, 2018.

CHEMICAL REACTION ENGINERING – I REF NO: ChE/T/312/2018

Group – A [50 marks]

Attempt any two questions. Al questions carry equal marks, i.e. 25.

1. A small reaction bomb fitted with a sensitive pressure-measuring device is flushed out and then filled with pure reactant A at 1-atm pressure. The operation is carried out at 25°C, a temperature low enough that the reaction does not proceed to any appreciable extent. The temperature is then raised as rapidly as possible to 100°C by plunging the bomb into boiling water, and the readings in the Table below are obtained. The stoichiometry of the reaction is 2A ---> B, and after leaving the bomb in the bath over the weekend the contents are analyzed for A; none can be found. Find a rate equation in units of moles, liters, and minutes which will satisfactorily fit the data tabulated below:

T,(min)	**π,(atm)**	**T,(min)**	**π,(atm)**
1	1.14	7	0.850
2	1.04	8	0.832
3	0.982	9	0.815
4	0.940	10	0.800
5	0.905	15	0.754
6	0.870	20	0.728

2. The data in the table below have been obtained on the decomposition of gaseous reactant A in a constant volume batch reactor at 100°C. The stoichiometry of the reaction is 2A →R +S. What size plug flow reactor (in liters) operating at 100°C and 1 atm can treat 100 mol A/hr in a feed consisting of 20% inerts, to obtain 95% conversion of A?

t,(sec)	p_A,(atm)	t,(sec)	p_A,(atm)
0	1.00	140	0.25
20	0.80	200	0.14
40	0.68	260	0.08
60	0.56	330	0.04
80	0.45	420	0.02
100	0.37		

3. Consider the autocatalytic reaction A ---> R, with $-r_A = 0.001\ C_AC_R$ mol/liter.s. We wish to process 1.5 liters/s of a feed containing $C_{A0} = 10$ mol/liter to the highest conversion possible in a reactor system consisting of four 100-liter mixed flow reactors connected as you wish and with any feed arrangement. Sketch your recommended design and feed arrangement and determine C_{Af} from this system.

4. The elementary irreversible aqueous-phase reaction A+B ----> 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.

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B. Chemical Engineering 3rd Year 1ST Semester Examination, 2018

Chemical Reaction Engineering-I

Time: Three Hours

Full Marks: 100

(50 marks for each part)
Use a separate Answer-Script for each part

Part II
<u>Answer any three questions</u>
All questions *do not* carry equal marks
Assume missing data, if any

1\. (i) For the elementary reactions $Q \begin{array}{l} \xrightarrow[k_1]{} R \xrightarrow{k_2} S \\ \xrightarrow[k_3]{} T \end{array}$, Find the mean residence time corresponding to maximum concentration of R in a CSTR. **[9]**

1.(ii) Liquid reactant P produces R and S by the following reactions:

$P \begin{array}{l} \nearrow R \\ \searrow S \end{array}$

$r_R = k_1 C_P$; $r_S = k_2 C_P^2$

The fresh feed with a composition C_{P0}=1.0 , C_{R0} = 0, C_{S0}= 0 is fed to two CSTRs in series. τ_1= 2.5 min, τ_2=5. 0 min. The composition in the first reactor C_{P1}=0.4 , C_{R1} = 0.4, C_{S1}= 0.2, determine the composition at the exit of second reactor. **[9]**

2\. (i) How would you construct a conversion-temperature-rate (*reaction pathways*) plot for a reversible first order reaction ? Hence, explain the graphical method of finding plug flow reactor size for adiabatic reversible first-order exothermic reaction. **[4+4]**

2.(ii) Write the eenergy balance equation for flow reactors (with heat effect) in terms of mean or constant heat capacities and find the expressions for conversion of the limiting reactant under (a)adiabatic condition and (b) with heat exchange. **[8]**

3\. (i) Express the following terms in RTD analyses of chemical reactor: 'Cumulative distribution Function' , 'Mean Residence Time' and 'Variance' and state their significance. **[3+2+3]**

3\. (ii) Define 'Bodenstein Number', "Dispersion Number" and "DamkÖhler Number" and state their significance pertaining to dispersion model for prediction of nonideal reactor behavior. **[3+ 2+ 3]**

4 . (i) Consider a first-order reaction P→Q , which is being conducted in a 5.0 m long 0.09 m-diameter tubular reactor . The reaction rate constant for this reaction is 0.35 min^{-1}. A pulse tracer injection test was conducted on this reactor and the results are shown in the following Table:

t (min)	0	1	2	3	4	5	6	7	8	9	10	12	14
C($\times 10^{-3}$ kg/m^3)	0	1.1	4.9	8.1	9.9	7.9	6.1	3.9	3.0	2.1	1.4	0.6	0

Compute the conversion employing (a) the dispersion model using closed-closed vessel boundary condition and (b) ideal PFR design equation. **[12]**

4.(ii) Stating the pertinent equations, explain the procedure to determine reactor dead volume using RTD data through applications of open-open boundary conditions (long tubes, $Pe_R>100$) as per dispersion model for nonideal reactor. **[4]**

5. (i) How would you model a real CSTR considering the two-parameters 'Bypassing' and 'Dead Space' ? How would you evaluate these model parameters using step tracer experiment?

[8]

5.(ii) Derive the equation to evaluate the conversion in a nonideal reactor by 'maximum mixedness model' considering a plug-flow reactor with side entrances.

[8]

NAME OF THE PAPER-SETTER: Prof. Rajat Chakraborty; Signature of paper-setter in full:

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