BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE (BITS) PILANI – Pilani Campus

Title: **K**inetics and **R**eactor **D**esign (CHE F311)- Mid-Semester Examination

Date: 13.10.2023 Time: 90 min. Max.Marks: 90

Note: ***State your assumption clearly if required & start a fresh page for answering each question***

1. The exothermic reaction $A \rightarrow B+C$ was carried out adiabatically and the following data recorded. The entering molar flowrate of A was 300 mol/min. [15 M]
   i. What are the PFR and CSTR volumes necessary to achieve 40% conversion?
   ii. What is the maximum conversion that can be achieved in a 105-dm^3 CSTR?
   iii. What conversion can be achieved if a 72-dm^3 PFR is followed in series by a 24-dm^3 CSTR?
   iv. What conversion can be achieved if a 24 dm^3 CSTR is followed in a series by a 72-dm^3 PFR?

X	0	0.2	0.4	0.45	0.5	0.6	0.8	0.9
$-r_A$ (mol/dm^3·min)	1.0	1.67	5.0	5.0	5.0	5.0	1.25	0.91

2. The first-order reversible liquid reaction A = R, C_{A0}= 0.5 mol/ lit, C_{R0}=0, takes place in a batch reactor. After 8 minutes, conversion of A is 33.3% while equilibrium conversion is 66.7%. Find the rate equation for this reaction. [8 M]

3. Find the first-order rate constant for the disappearance of A in the gas reaction $2A \rightarrow R$ if, on holding the pressure constant, the volume of the reaction mixture, starting with 80% A, decreases by 20% in 3 min. [7 M]

4. The homogeneous gas decomposition of phosphine $4\ PH_3(g) \rightarrow P_4\ (g) + 6H_2\ (g)$ proceeds at 649 ºC with the first-order rate $-r_{PH3}=(10/hr)C_{PH3}$. What size of plug flow reactor operating at 649 ºC and 460 kPa can produce 80% conversion of a feed consisting of 40 mol of phosphine and 20 mol of argon per hour? [15 M]

5. The first order homogeneous gas phase reaction $A \rightarrow 2.5\ R$ is carried out in an isothermal batch reactor at 2 atm pressure with 80 mole % A and 20 mole % inerts, and the volume increased by 60% in 20 minutes. In the case of a constant-volume reactor, determine the time required (for the same reaction) for the pressure to rise to 8 atm if the initial pressure is 5 atm, 2 atm of which consists of inerts. (i.e., the contribution of inerts present is 2 atm to the initial total pressure of 5 atm) [20 M]

6. Our company has a continuous stirred fermentation process (second order irreversible, constant hold-up) in an open tank where the liquid is kept at a constant height. The tank has a catwalk around it so the sediment can be removed. The process has been run for many years by a loyal employee who is a bit overweight and has been rumored to have a drinking habit. Yesterday, he was missing for the first time in many years. The tank has a volume of 1000 liters. The data log shows that the conversion from the process decreased from its normal 75% to 72%, but the flow rate did not change. (Assume the substances in the tank, and the person have the same density- equal to 1.0 kg/ lit)
   i. How overweight was he?
   ii. If you were the design engineer for this process, you could be in considerable trouble. How should you have modified the process to avoid such accidents? [10 M]

7. The liquid-phase reaction was carried out in a CSTR. For an entering concentration of 2 rnol/dm^3. the conversion was 40%. For the same reactor volume and entering conditions as the CSTR, the expected PFR conversion is 48.6%. However. the PFR conversion was amazingly 50% exactly. Brainstorm reasons for the disparity. Quantitatively show how these conversions came about (i.e., the expected and actual conversions). [15 M]

ALL THE BEST

The following may or may not be required to solve the above problems

$$\Rightarrow \frac{1}{C_A} - \frac{1}{C_{A0}} = kt$$

$$\frac{1}{C_A} - \frac{1}{C_{A0}} = \frac{1}{C_{A0}} \frac{X_A}{1 - X_A} = 2kt, \qquad M = 2$$

$$\ln \frac{C_{A0}(C_0 - C_A)}{C_A(C_0 - C_{A0})} = \ln \frac{C_R/C_{R0}}{C_A/C_{A0}} = C_0 kt = (C_{A0} + C_{R0})\, kt$$

$$\ln \frac{M + X_A}{M(1 - X_A)} = C_{A0}(M + 1)kt = (C_{A0} + C_{R0})kt$$

$$\frac{\ln (C_{A0}/C_A)}{C_{A0} - C_A} = -k_2 + \frac{k_1 t}{C_{A0} - C_A}$$

$$\ln \frac{X_{A_e} - (2X_{Ae} - 1)X_A}{X_{Ae} - X_A} = 2k_1 \left(\frac{1}{X_{Ae}} - 1\right) C_{A0} t$$

$$\frac{(1+\varepsilon_A)\Delta V}{V_0 \varepsilon_A - \Delta V} + \varepsilon_A \ln\left(1 - \frac{\Delta V}{\varepsilon_A V_0}\right) = kC_{A0}t$$