V SEMESTER B.TECH (CHEM. ENGG)

MAKE UP SEMESTER EXAMINATION JAN 2023

CHE-3151 CHEMICAL REACTION ENGINEERING

Type: DES

Q1A. At room temperature sucrose is hydrolyzed by the catalytic action of the enzyme sucrase as follows Sucrose → products.

Starting with a sucrose concentration C_{A0}= 1 mmol/l and an enzyme concentration C_{E0} = 0.01 mmol/l, the following kinetic data are obtained in a batch reactor

C_A mmol/l	0.84	0.68	0.53	0.38	0.27	0.16	0.09	0.04	0.018	0.006	0.0025
t hr	1	2	3	4	5	6	7	8	9	10	11

Determine whether these data can be reasonably fitted by the kinetic equation $-r_A = k_3 C_A C_{E0}/(C_A + C_M)$, where C_M is Michaelis constant. (3) **CO1**

Q1B. At high temperatures, nitrogen dioxide decomposes to nitric oxide and oxygen occurs in a batch reactor at 300 ^{0}C.

$2NO_2\,(g) \rightarrow 2NO\,(g) + O_2\,(g)$

Experimental data for the reaction with the initial concentrations of NO_2 are listed in the following table:

Time (min)	0	15	22	28	33	40	49
C_{NO2} (g mol/L)	3.571	1.08	0.816	0.674	0.589	0.500	0.419

Determine the reaction order with the provided data using the integral method and calculate the reaction-rate constant. (3) **CO1**

Q1C. For the following enzymatic reactions derive rate law for Enzyme-Substrate-Complex-1 ($r_{E.S}$), Enzyme-Substrate-Complex-2 ($r_{E.Q}$) and product (r_P) expressed only in concentrations of enzyme (C_E), substrate (C_S), product species (C_Q):

1. $E + S \leftrightarrow E.S$
   Enzyme + Substrate 1 ↔ Enzyme-Substrate-Complex 1
2. $E.S \rightarrow Q$
   Enzyme-Substrate-Complex 1 → Product Species Q
3. $E + Q \leftrightarrow E.Q$
   Enzyme + Product Species Q ↔ Enzyme-Substrate-Complex 2
4. $E.Q \rightarrow P + E$
   Enzyme-Substrate-Complex 2 → Product P + Enzyme (4) **CO1**

Q2A. For the data in question 1A, find size of A CSTR required for a conversion of 96% when volumetric flow rate is 20 l/hr. (4) **CO2**

Q2B. List the assumptions made in an ideal batch, plug flow and mixed flow reactor. (3) **CO2**

Q2C. From a gas-phase oxidation reaction of ammonia, nitric oxide is prepared and used to produce nitric acid. $4\ NH_3 + 5O_2 \rightarrow 4\ NO + 6\ H_2O$

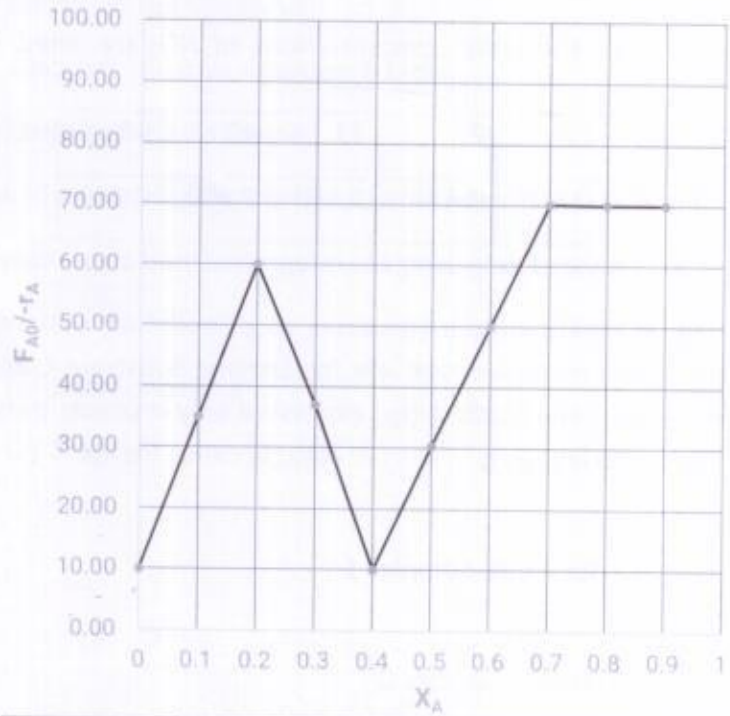
Air with 15% NH_3 is sent as feed at 8.2 atm and 227 ^{0}C.

Calculate the Concentration of ammonia in the feed and prepare the stoichiometric table for constant volume reactor with ammonia as basis of calculation. (3) **CO2**

Q3A. For a first order reaction VPFR < V recycle reactor < V CSTR. True/ False. Justify. (4) **CO3**

Q3B. Define Damkohler number. Explain its significance. (2) **CO3**

Q3C. Compute the following from the following reaction data and flow rate F_{A0} = 100 mol/min:



X	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
$-r_A$ (mol/dm^3·min)	10.00	2.85	1.67	2.70	10.00	3.30	2.00	1.43	1.43	1.43
$F_{A0}/-r_A$ (dm^3)	10.00	35.09	60.00	37.04	10.00	30.30	50.00	70.00	70.00	70.00

a) Compare the volume of mixed flow reactor required for 40% and 80% conversion.

b) Compare the volume of mixed flow reactor and plug flow reactor required for 70% conversion.

c) Recommend a series of reactors for with optimal total volume to attain 70% conversion (4) **CO3**

Q4A. Using separate feeds of A and B sketch the contacting pattern and reactor conditions which would best promote the formation of product D for the below series-parallel reactions in a flow system.

$A + B \rightarrow D$; $-r_{1A} = k_1 C_A^2 C_B$

$A + B \rightarrow U$; $-r_{2A} = k_2 C_A C_B^2$ (3) **CO4**

Q4B. For the following reaction, compare the maximum obtainable concentration of R in a plug flow reactor and mixed flow reactor: $A \xrightarrow{k_1} R \xrightarrow{k_2} S$; $k_1 = 0.1\ s^{-1}$, $k_2 = 0.1\ s^{-1}$ (2) **CO4**

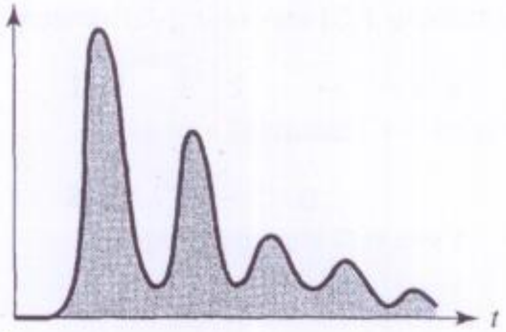
Q4C. A) Define with examples: i) homogeneous reactions ii) heterogeneous reactions

B) Define (i) limiting reactant (ii) activation energy (iii) Arrhenius law. (5) **CO4**

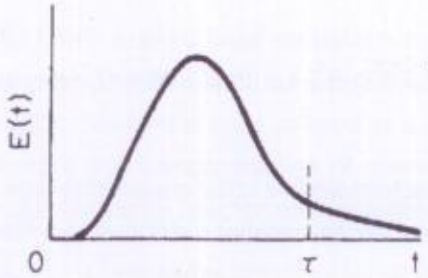
Q5A. Diagnose the reactor problem from the response curves shown:

i)

ii)



iii)



(3) **CO5**

Q5B. Tracer hytane was injected as a pulse into the reactor with a flow rate of 10 dm^3/min and following effluent concentration was measured as the function of time.

T (min)	0	1	2	3	4	5	6	8	10	15	20	25	30	35	40
C(t) (mol/lit)	0	305	381	388	371	348	320	280	244	154	79	32	21	14	6

(a) Construct the C(t) curve

(b) Calculate the mean residence time.

(c) Construct the E(t) curve.

Fraction of material spends time longer than 6 min in the reactor. (5) **CO5**

Q5C. Describe the following by explaining diagnostics in the reactor diagram:

(a) Short-circuiting

(b) Stagnant zones (2) **CO5**