MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent unit of MAHE, Manipal)

V[th] SEMESTER B.TECH. (CHEMICAL ENGINEERING)
END SEMESTER EXAMINATIONS November-2022
SUBJECT: CHEMICAL REACTION ENGINEERING [CHE 3151]

Time: 180 Min **Date: 26-11-2022** **Marks: 50 Marks**

Instructions to Candidates:
- Answer **ALL** the questions.
- Missing data may be suitable assumed.
- Use graphs wherever relevant.

1A)	Consider the reaction A-> R with $-r_A = k_1C_A/(1+k_2C_A)$. How do you test this rate for a given experimental data set of concentration vs time?	4M
1B)	For the data in question 1, find size of A CSTR required for a conversion of 96% when volumetric flow rate is 20 l/hr. Given $k_1 = 10s^{-1}$, $k_2 = 1\ (mol/l)^{-1}$, $C_{A0} = 1$ mol/l.	3M
1C)	Using separate feeds of A and B sketch the contacting pattern and reactor conditions which would best promote the formation of product R for the below elementary reactions in a flow system. $A + B \rightarrow R$ $2A \rightarrow S$	3M
2A)	Modify the two-parameter model for a first order reaction carried out in a tank reactor with (ONLY) bypassing. Derive an expression for conversion of reactant in terms of adjustable parameter/s and known parameters.	4M
2B)	Prove that recycle reactor is better than a CSTR or PFR to perform an autocatalytic reaction for high conversion.	3M
2C)	List the assumptions made in an ideal batch, plug flow and mixed flow reactor.	3M

3A) A gaseous feed of pure A (2 mol/l, 100 mol/min) decomposes to give a variety of products in a plug flow reactor. The kinetics of the conversion is represented by

$A \rightarrow 2.5\,P$

$-r_A = 10\ \text{min}^{-1}\ C_A$. Find the expected conversion in a 22-litre reactor. **3M**

3B) Define i) selectivity ii) yield iii) conversion iv) ϵ. **2M**

3C) Tracer was injected as a pulse to the reactor of flow rate 10 dm^3/min and following concentration is measured at the outlet. **5M**

t (min)	0	1	2	3	4	5	6	8	10	15	20	25	30	35	40
$C(t) \times 10^5$ (mol/dm^3)	0	622	812	831	785	720	650	523	418	238	136	77	44	25	14

(a) Calculate the mean residence time and variance.

(b) Fraction of material spends time between 2 and 4 min in the reactor.

(c) Fraction of material spends time longer than 6 min in the reactor.

4A) A gas-phase decomposition reaction takes place in a batch reactor at 200 °C. **3M**

$A \rightarrow B + C$

Time (min)S	0	6	12	18	24	30	36
C_{Br_2} (g mol/L)	5.70	4.00	2.70	1.80	1.25	0.85	0.60

Determine the reaction order for from the given data using the integral method and calculate the reaction-rate constant.

4B) From a gas-phase oxidation reaction of ammonia, nitric oxide is prepared and used to produce nitric acid. $4\ NH_3 + 5O_2 \rightarrow 4\ NO + 6H_2O$ Air with 15% NH_3 is sent as feed at 8.2 atm and 227 °C. **3M**

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

4C) Define (i) order of the reaction (ii) molecularity. Deduce the rate laws for following elementary reactions: **4M**

$(a)\ CH_3COOC_2H_5 + C_4H_9OH \leftrightarrow CH_3COOC_4H_9 + C_2H_5OH$

$(b)\ 2CH_3NH_2 \leftrightarrow (CH_3)_2NH + NH_3$

$(c)\ (CH_3CO)_2O + H_2O \leftrightarrow 2CH_3COOH$

$(d)\ C_2H_6 \rightarrow C_2H_4 + H_2$

5A) 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): **4M**

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

4. $E.Q \rightarrow P + E$

   Enzyme-Substrate-Complex 2 → Product P + Enzyme

5B) Define with mathematical expression the moments of residence time distribution. **2M**

5C) Compute the following from the following reaction data: **4M**

X	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
$-r_A$ (mol/dm³·min)	2	2.9	5	5	3	2	5	5	2.2	1.38
$F_{A0}/-r_A$ (dm³)	50	34.5	20	20	33.3	50	20	20	45.5	72.5

a) Compare the volume of mixed flow reactor required for 50% and 70% conversion.

b) Compare the volume of mixed flow reactor and plug flow reactor required for 90% conversion.

Recommend a series of reactors for with optimal total volume to attain

c) 50% conversion

d) 90% conversion

****