Enrolment No./Seat No_______________

GUJARAT TECHNOLOGICAL UNIVERSITY

BE- SEMESTER–VI EXAMINATION – WINTER 2025

Subject Code:3160506 Date:17-11-2025

Subject Name:Chemical Reactions Engineering I

Time:02:30 PM TO 05:00 PM Total Marks:70

Instructions:

1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**
4. **Simple and non-programmable scientific calculators are allowed.**

MARKS

Q.1 (a) Classify reactions and give suitable industrial example of such reaction. **03**

(b) Discuss sensitivity of activation energy with reference to different parameters. **04**

(c) Performance of PFR is better than CSTR for all positive order reactions. Justify above statement with suitable arguments and schematic diagram. **07**

Q.2 (a) $N_2 + 3H_2 \longrightarrow 2NH_3$. With suitable justification classify this reaction as elementary or non elementary reaction. **03**

(b) For the stoichiometry $A + B \longrightarrow$ (products), find the reaction orders with respect to A and B. **04**

C_A	4	1	1
C_B	1	1	8
r_a	2	1	4

(c) The first-order reversible liquid reaction **07**

$A \rightleftarrows R$, $C_{A0} = 0.5$ 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.

OR

(c) Pure gaseous A at about 3 atm and 30°C (120 mmol/liter) is fed into a 1 liter mixed flow reactor at various flow rates. There it decomposes, and the exit concentration of A is measured for each flow rate. From the following data find a rate equation to represent the kinetics of the decomposition of A. Assume that reactant A alone affects the rate. **07**

$A \longrightarrow 3R$

v_0	0.06	0.48	1.5	8.1
C_A	30	60	80	105

Q.3 (a) Given a gaseous feed, $C_{A0} = 100$, $C_{B0} = 200$, $A + B \longrightarrow R + S$, $X_A = 0.8$. Find X_B , C_A, C_B. **03**

(b) The pyrolysis of ethane proceeds with an activation energy of about 300 kJ/mol. How much faster is the decomposition at 650 °C than at 500 °C? **04**

(c) At present the elementary liquid-phase reaction $A + B \longrightarrow R + S$ takes place in a plug flow reactor using equimolar quantities of A and B. Conversion is 96%, $C_{A0} = C_{B0} = 1$ mol/liter. If a mixed flow reactor ten times as large as **07**

the plug flow reactor were hooked up in series with the existing unit, which unit should come first and by what fraction could production be increased for that setup?

OR

Q.3 **(a)** Derive the equation for Irreversible Unimolecular-type first order reaction. **03**

(b) Why a larger CSTR as first reactor in three reactor sequence choice is worst selection for an arrangements of sequence of one PFR and two different size CSTRs in series for 2nd order reaction. **04**

(c) Derive the performance equation for equal size CSTR's arranged in series. **07**

Q.4 **(a)** Describe the optimum temperature progression and its application. **03**

(b) For two equal sized CSTR in series, suggest procedure to be followed to find optimum intermediate conversion to have minimum volume of both reactors. **04**

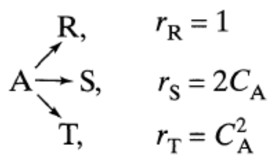
(c) Derive a relation for overall fractional yield in PFR for following reaction in parallel **07**

A $\longrightarrow$ R and A $\longrightarrow$ S.

OR

Q.4 **(a)** A liquid reactant stream (1 mol/liter) passes through two mixed flow reactors in a series. The concentration of A in the exit of the first reactor is 0.5 mol/liter. Find the concentration in the exit stream of the second reactor. The reaction is second-order with respect to A and $V_2/V_1 = 2$. **03**

(b) Consider the parallel decomposition of A of different orders **04**

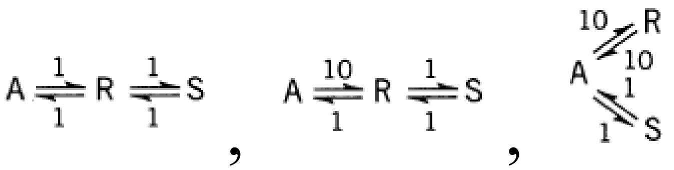


Determine the maximum concentration of desired product obtainable in

(a) plug flow,

(b) mixed flow.

(c) Draw schematic diagram of concentration Vs time for following reactions, **07**



Q.5 **(a)** Discuss various non-idealities that can be present in a CSTR. **03**

(b) Draw C curve and E curve for a pulse input in ideal PFR. **04**

(C) A pipeline (10 cm I.D., 19.1 m long) simultaneously transports gas and liquid from here to there. The volumetric flow rate of gas and liquid are 60 000 cm3/s and 300 cm3/s, respectively. Pulse tracer tests on the fluids flowing through the pipe give results as shown in Fig A. below What fraction of the pipe is occupied by gas and what fraction by liquid? **07**

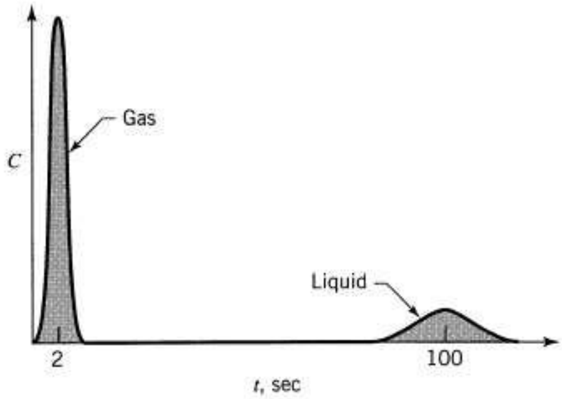


Figure P11.6

OR

Q.5 **(a)** Discuss various non-idealities that can be present in a PFR. **03**

(b) Suggest relative changes in t_{bar} value of various non-idealities present in CSTR. Explain with schematic diagram of C curve for all such cases. **04**

(c) A pulse of concentrated NaCl solution is introduced as tracer into the fluid entering a vessel ($V = 1\ m^3$, $v = 1\ m^3/min$) and the concentration of tracer is measured in the fluid leaving the vessel. Develop a flow model to represent the vessel from the tracer output data sketched in Fig. as shown below. **07**

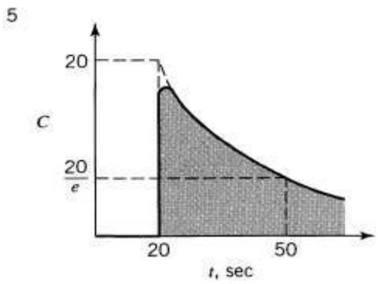


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Table 5.1 Performance Equations for nth-order Kinetics and $\varepsilon_A = 0$

	Plug Flow or Batch		Mixed Flow	
$n = 0$ $-r_A = k$	$\frac{k\tau}{C_{A0}} = \frac{C_{A0} - C_A}{C_{A0}} = X_A$	**(20)**	$\frac{k\tau}{C_{A0}} = \frac{C_{A0} - C_A}{C_{A0}} = X_A$	
$n = 1$ $-r_A = kC_A$	$k\tau = \ln\frac{C_{A0}}{C_A} = \ln\frac{1}{1 - X_A}$	**(3.12)**	$k\tau = \frac{C_{A0} - C_A}{C_A} = \frac{X_A}{1 - X_A}$	**(14*a*)**
$n = 2$ $-r_A = kC_A^2$	$k\tau C_{A0} = \frac{C_{A0} - C_A}{C_A} = \frac{X_A}{1 - X_A}$	**(3.16)**	$k\tau = \frac{(C_{A0} - C_A)}{C_A^2} = \frac{X_A}{C_{A0}(1 - X_A)^2}$	**(15)**
any n $-r_A = kC_A^n$	$(n-1)C_{A0}^{n-1}k\tau = \left(\frac{C_A}{C_{A0}}\right)^{1-n} - 1 = (1 - X_A)^{1-n} - 1$	**(3.29)**	$k\tau = \frac{C_{A0} - C_A}{C_A^n} = \frac{X_A}{C_{A0}^{n-1}(1 - X_A)^n}$	
$n = 1$ $A \underset{2}{\overset{1}{\rightleftharpoons}} R$ $C_{R0} = 0$	$k_1\tau = \left(1 - \frac{C_{Ae}}{C_{A0}}\right)\ln\left(\frac{C_{A0} - C_{Ae}}{C_A - C_{Ae}}\right) = X_{Ae}\ln\left(\frac{X_{Ae}}{X_{Ae} - X_A}\right)$		$k_1\tau = \frac{(C_{A0} - C_A)(C_{A0} - C_{Ae})}{C_{A0}(C_A - C_{Ae})} = \frac{X_A X_{Ae}}{X_{Ae} - X_A}$	
General rate	$\tau = \int_{C_A}^{C_{A0}}\frac{dC_A}{-r_A} = C_{A0}\int_0^{X_{Af}}\frac{dX_A}{-r_A}$	**(19)**	$\tau = \frac{C_{A0} - C_A}{-r_{Af}} = \frac{C_{A0}X_A}{-r_{Af}}$	**(13)**

Enrolment No./Seat No_______________

GUJARAT TECHNOLOGICAL UNIVERSITY

BE- SEMESTER–VI (NEW) EXAMINATION – WINTER 2024

Subject Code:3160506 **Date:25-11-2024**

Subject Name:Chemical Reactions Engineering I

Time:02:30 PM TO 05:00 PM **Total Marks:70**

Instructions:

1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**
4. **Simple and non-programmable scientific calculators are allowed.**

MARKS

Q.1 **(a)** Explain homogeneous and heterogeneous reactions with suitable example. **03**

(b) How can you identify dead zone and bypass non-idealities present in CSTR? Explain with suitable schematic diagrams. **04**

(c) Derive performance equation for PFR with recycle. **07**

Q.2 **(a)** Explain that non-elementary reactions are taking place in multiple steps. **03**

(b) Write short note on Activation Energy. **04**

(c) Pure gaseous A at about 5 atm and 50 °C (150 mmol/liter) is fed into a 2 liter mixed flow reactor at various flow rates. There it decomposes, and the exit concentration of A is measured for each flow rate. From the following data find a rate equation to represent the kinetics of the decomposition of A. Assume that reactant A alone affects the rate. **07**

Reaction is $A \rightarrow 3R$

v_0, lit/min	0.06	0.48	1.5	8.1
C_A, mmol/lit	30	60	80	105

OR

(c) An aqueous feed of A and B (500 liter/min, 200 mmol A/liter, 200 mmol B/liter) is to be converted to product in a mixed flow reactor. The kinetics of the reaction are represented by **07**

$A + B \longrightarrow R$, $-r_A = 120\, C_A C_B$ mol/(lit.min)

Find the volume of reactor needed for 99% conversion of A to product.

Q.3 **(a)** Derive rate of reaction for homogeneous catalytic reaction. **03**

(b) Derive rate expression for 2nd order reaction, $A + B \longrightarrow R + S$, where $C_{A0}=C_{B0}$ **04**

(c) Show that performance of multiple PFR in series is equal to performance of single PFR having total volume of single PFR and multiple PFR equal and volumetric flow rate remains same for both cases. **07**

OR

Q.3 **(a)** Given a gaseous feed, $C_{A0} = 100$, $C_{B0} = 200$, $A + B \longrightarrow R + S$, $X_A = 0.9$. Find X_B, C_A, C_B. **03**

(b) Write short note on Multiple CSTRs in series. **04**

(c) For multiple reactor, justify with suitable diagram that for all positive order reaction, PFR+small CSTR + large CSTR is best choice than any other combinations. **07**

Q.4 (a) Suggest selection of maximum operating temperature for, **03**
i) exothermic irreversible reaction,
ii) exothermic reversible reaction
iii) endothermic reversible reactions

(b) Draw schematic diagram for optimal temperature progression for adiabatic reactions in CSTR and explain its salient features. **04**

(c) Derive a relation for overall fractional yield in PFR for following reaction in parallel **07**
$A \longrightarrow R$ and $A \longrightarrow S$.

OR

Q.4 (a) 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 following systems of elementary reactions. **03**
$A + B \longrightarrow R$ and $A \longrightarrow S$ (Continuous flow reactor)

(b) Draw schematic diagram of concentration Vs time for following reactions, **04**

$A \xrightarrow{1} R \xrightarrow{1} S$, $A \underset{1}{\overset{1}{\rightleftharpoons}} R \xrightarrow{1} S$, $A \xrightarrow{1} R \underset{1}{\overset{1}{\rightleftharpoons}} S$

(c) A liquid reactant stream (2 mol/liter) passes through two mixed flow reactors in a series. The concentration of A in the exit of the first reactor is 0.7 mol/liter. Find the concentration in the exit stream of the second reactor. The reaction is second-order with respect to A and $V_2/V_1 = 1.5$. **07**

Q.5 (a) Write short note on Uses of RTD studies. **03**

(b) Draw an discuss C, E and F curve for ideal PFR for pulse input. **04**

(C) A pipeline (10 cm I.D., 19.1 m long) simultaneously transports gas and liquid from here to there. The volumetric flow rate of gas and liquid are 60 000 cm^3/s and 300 cm^3/s, respectively. Pulse tracer tests on the fluids flowing through the pipe give results as shown in Fig A. below What fraction of the pipe is occupied by gas and what fraction by liquid? **07**

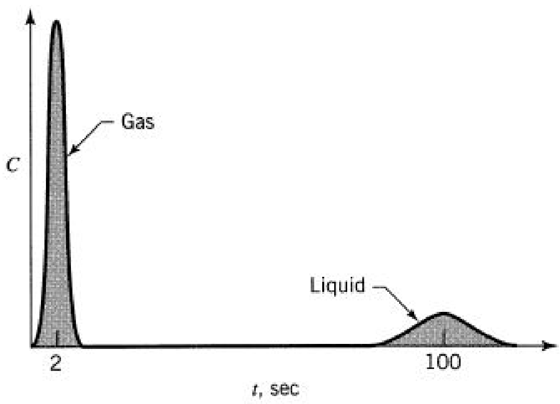

Figure P11.6

OR

Q.5 (a) RTD of all the components for ideal PFR is same. Justify this statement. **03**

(b) Draw C and E curve for ideal CSTR, PFR with bypass, PFR with dead zone reactions for pulse input. **04**

(c) **A** pulse input to a vessel gives the results shown in Fig. below **07**
(a) Check the material balance with the tracer curve to see whether the results are consistent.
(b) If the result is consistent, determine *t,* V and sketch the E curve.

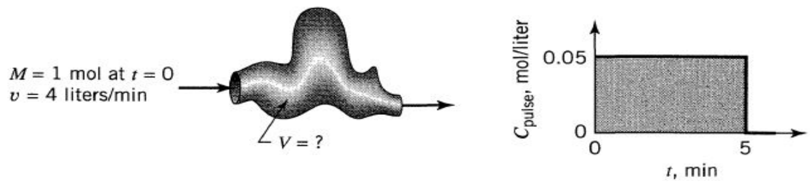

Table 5.1 Performance Equations for *n*th-order Kinetics and $\varepsilon_A = 0$

	Plug Flow or Batch		Mixed Flow	
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$n = 1$, $-r_A = kC_A$	$k\tau = \ln\frac{C_{A0}}{C_A} = \ln\frac{1}{1 - X_A}$	**(3.12)**	$k\tau = \frac{C_{A0} - C_A}{C_A} = \frac{X_A}{1 - X_A}$	**(14*a*)**
$n = 2$, $-r_A = kC_A^2$	$k\tau C_{A0} = \frac{C_{A0} - C_A}{C_A} = \frac{X_A}{1 - X_A}$	**(3.16)**	$k\tau = \frac{(C_{A0} - C_A)}{C_A^2} = \frac{X_A}{C_{A0}(1 - X_A)^2}$	**(15)**
any n, $-r_A = kC_A^n$	$(n-1)C_{A0}^{n-1}k\tau = \left(\frac{C_A}{C_{A0}}\right)^{1-n} - 1 = (1 - X_A)^{1-n} - 1$	**(3.29)**	$k\tau = \frac{C_{A0} - C_A}{C_A^n} = \frac{X_A}{C_{A0}^{n-1}(1 - X_A)^n}$	
$n = 1$, $A \underset{2}{\overset{1}{\rightleftarrows}} R$, $C_{R0} = 0$	$k_1\tau = \left(1 - \frac{C_{Ae}}{C_{A0}}\right)\ln\left(\frac{C_{A0} - C_{Ae}}{C_A - C_{Ae}}\right) = X_{Ae}\ln\left(\frac{X_{Ae}}{X_{Ae} - X_A}\right)$		$k_1\tau = \frac{(C_{A0} - C_A)(C_{A0} - C_{Ae})}{C_{A0}(C_A - C_{Ae})} = \frac{X_A X_{Ae}}{X_{Ae} - X_A}$	
General rate	$\tau = \int_{C_A}^{C_{A0}} \frac{dC_A}{-r_A} = C_{A0}\int_0^{X_{Ae}} \frac{dX_A}{-r_A}$	**(19)**	$\tau = \frac{C_{A0} - C_A}{-r_{Af}} = \frac{C_{A0}X_A}{-r_{Af}}$	**(13)**

Seat No.: ________ Enrolment No.___________

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER–VI (NEW) EXAMINATION – WINTER 2023

Subject Code:3160506 Date:05-12-2023

Subject Name: Chemical Reactions Engineering I

Time:02:30 PM TO 05:00 PM Total Marks:70

Instructions:

1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**
4. **Simple and non-programmable scientific calculators are allowed**

Q.1 A 1) Justify- Molecularity of reaction can never be more than three. **3**

2) Why can the order of reaction be zero, but the molecularity of a reaction cannot be?

3) Define an intermediate. What are the different types of intermediates that are suggested by the chemistry of the materials?

B Discuss merits and demerits of batch and continuous modes of reactor operation. **4**

C A human being (75 kg) consumes about 6000 kJ of food per day. Assume that the food is all glucose and that the overall reaction is **7**

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$, $-\Delta Hr = 2816$ kJ

Find man's metabolic rate (the rate of living, loving, and laughing) in terms of moles of oxygen used per m^3 of person per second. (Assume density of man = 1000 kg/m^3)

Q.2 A The activation energy of a bimolecular reaction is about 9150 cal/mol. How much faster does this reaction take place at 500 K than at 400 K? **3**

B Write a short note on temperature dependency of reaction rate constant from Arrhenius law. Compare the same with transition state and collision theories. **4**

C The reaction between nitric oxide and oxygen given below **7**

$$2NO + O_2 \rightarrow 2NO_2$$

follows the rate law $-\frac{d[O_2]}{dt} = k[NO]^2[O_2]$

Suggest a reaction mechanism which is consistent with this rate law.

OR

C Explain theory – Analysis of total pressure data obtained in constant-volume system. **7**

Q.3	**A**	On doubling the concentration of the reactants, the rate of reaction increase four times. Find the order of reaction.	**3**
	B	It is stated that the half-life method for finding reaction order can be used to any fractional-life data. Do this, defining $t_{1/m}$ as the time required for the concentration of the reactant to drop to $1/m^{th}$ of its original/initial value.	**4**
	C	Prove that N number of plug flow reactor connected in series and its total volume V gives the same conversion as a single plug flow reactor of volume V.	**7**
		OR	
Q.3	**A**	Differentiate between Integral and Differential method of analysis for analysing batch reactor data.	**3**
	B	Define: Space time, Space velocity, Holding time, Mean residence time.	**4**
	C	Derive performance equation for steady-state mixed flow reactor and discuss fractional conversion in terms of Damkohler number.	**7**
Q.4	**A**	Define an equilibrium state and discuss characteristics of chemical equilibrium.	**3**
	B	What is the use of tracer? Discuss desired characteristics of tracer.	**4**
	C	Discuss the effect of pressure on equilibrium conversion as predicted by thermodynamics keeping temperature fixed.	**7**
		OR	
Q.4	**A**	Discuss effect of temperature on heat of reaction.	**3**
	B	Sketch and explain RTD curves for Ideal Plug Flow Reactor and Ideal Mixed flow Reactor.	**4**
	C	Discuss the effect of temperature on equilibrium conversion as predicted by thermodynamics keeping pressure constant.	**7**
Q.5	**A**	Classify chemical reactions on the basis of (a) number of phases involved and (b) heat or reaction with suitable example.	**3**
	B	Which are various non-idealities that can exist in a reactor? Also suggest solution to remove such non-idealities from the reactor.	**4**
	C	Write a short note on Qualitative product distribution for reactions in parallel.	**7**
		OR	
Q.5	**A**	Explain the method for searching the mechanism of chemical reaction.	**3**
	B	Explain equal sized mixed flow reactors connected in series.	**4**
	C	Derive the performance equation of recycle reactor and discuss its graphical representation for constant and variable density.	**7**

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GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER–VI(NEW) EXAMINATION – WINTER 2022

Subject Code:3160506 Date:14-12-2022

Subject Name:Chemical Reactions Engineering I

Time:02:30 PM TO 05:00 PM Total Marks:70

Instructions:

1. **Attempt all questions.**
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			MARKS
Q.1	**(a)**	Define rate constant. Derive the unit of rate constant.	**03**
	(b)	Discuss the variables affecting the rate of reaction.	**04**
	(c)	Derive performance equation for a CSTR.	**07**
Q.2	**(a)**	Define space time, space velocity& mean residence time.	**03**
	(b)	Discuss in detail about Integral method and Half life Method.	**04**
	(c)	Discuss the analysis of total pressure data obtained in a constant volume system and establish the relation used to calculate the partial pressure of gaseous component in reaction mixture.	**07**
		OR	
	(c)	Show that $$\ln \frac{M - X_A}{M(1-X_A)} = C_{A0}(M-1)kt, M \pm 1$$ for second order irreversible bimolecular type reaction A + B $\longrightarrow$ Products with different concentration of reactants A and B.	**07**
Q.3	**(a)**	State the points to be considered to find the size of reactor required for given duty and for a given temperature progression	**03**
	(b)	Discuss method of maximization of rectangles applied to find the optimum intermediate conversion and optimum sizes of two mixed flow reactors in series.	**04**
	(c)	An aqueous reactant stream with C_{AO}= 4 mol/lit passes through a mixed flow reactor followed by a plug flow reactor. The reaction is 2[nd] order with respect to A. The volume of plug flow reactor is 3 times that of the mixed flow reactor. Find the concentration of A at the exit of the plug flow reactor if the concentration of A in the mixed flow reactor is 1 mol/lit.	**07**
		OR	
Q.3	**(a)**	Discuss fractional yield, overall yield and selectivity for parallel reaction	**03**
	(b)	Discuss autocatalytic reaction with conversion-time and rate concentration Curves.	**04**
	(c)	When elementary 2nd order liquid reaction 2A $\rightarrow$ 2R carried in a plug flow reactor, operated isothermally, with a recycle ratio of unity, conversion is found to be 66.67%. Determine the conversion if the recycle stream is shut off.	**07**
Q.4	**(a)**	Discuss equal sized mixed flow reactors in series	**03**
	(b)	Explain Plug Flow Reactors in Series and in Parallel with	**04**

equation.

(c) Discuss in detailed about product distribution for parallel reaction. **07**

OR

Q.4 **(a)** Define zero order reaction with suitable example. **03**

(b) Define Overall Fractional yield and Instantaneous fractional yield for the decomposition of A into product R. **04**

(c) First order unimolecular irreversible reaction in series **07**
$A \longrightarrow R \longrightarrow S$ takes place with specific reaction rate k1 and k2. Express the variation of concentration of A, R and S with time. Find the expression for the time when formation of R becomes maximum.

Q.5 **(a)** Define Residence Time Distribution and explain E-Curve. **03**

(b) A closed vessel has flow for which dispersion number is 0.3. We wish to represent this vessel by tanks in series model. What value of number of tanks should be selected? **04**

(c) Write a short note on equilibrium constants from thermodynamics clearly indicating the equations. **07**

OR

Q.5 **(a)** List out characteristics of good tracer **03**

(b) From the first principle prove that for a back mix reactor **04**
(i) $E\theta = e^{-\theta}$ and (ii) $F\theta = 1- e^{-\theta}$

(c) Find out relation between conversion and temperature **07**
(a) Between 0 °C and 100 °C determine the equilibrium conversion of A for the aqueous reaction

$$A \leftrightarrow B$$

$\Delta G^{o}_{298} = -3375$ cal/mol; $\Delta H^{o}_{r,298} = -18{,}000$ cal/mol
Plot a graph between conversion and temperature.
(b) What the restrictions should be placed on a reactor operating isothermally if we have to obtain fractional conversion of 75% or higher?

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