



SUMMER-19 EXAMINATION
Model Answer

Subject title: Chemical Reaction Engineering

Subject code

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Important Instructions to examiners:

- 1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
- 2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
- 3) The language errors such as grammatical, spelling errors should not be given more importance (Not applicable for subject English and Communication Skills).
- 4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
- 5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
- 6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
- 7) For programming language papers, credit may be given to any other program based on equivalent concept.



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Q No.	Answer	Marking scheme
1 a	Attempt any THREE of the following	12
1a i	Factors affecting the rate of a chemical reaction : 1. In homogeneous system temperature, pressure and composition are the variables. 2. In heterogeneous system, since more than one phase is involved, material have to move from phase to phase during reaction, hence the rate of mass transfer is important. 3. rate of heat transfer 4. Catalyst 5. Nature of reactants 6. Surface area available. 7. Intensity of light if reaction is light sensitive.	1 mark each for any four factors.
1a ii	Definition: 1) Internal energy (U): It is the energy stored in the system by virtue of the configuration and motion of the molecules constituting the system. 2) Gibb's free energy: Gibb's free energy is the energy actually available to do useful work. It predicts the feasibility and equilibrium conditions for chemical reactions at constant temperature and pressure. 3) Entropy: Entropy(s) is the measure of the total disorder or randomness of the system or it is a measure of the unavailable energy to perform useful work. 4) Fugacity: It is a kind of fictitious pressure used for real gases. ie it is a measure of pressure for real gases.	1 mark each



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1a	iii	Space time: It is the time required to process one reactor volume of feed measured at specified condition. $\tau = \frac{1}{s} = \frac{C_{A0}V}{F_{A0}}$ Unit Unit is unit of time (seconds, minute, etc) Space velocity It is the number of reactor volume of feed at specified conditions which can be treated in unit time. $S = \frac{1}{\tau} = \frac{F_{A0}}{C_{A0}V}$ Unit Unit is $time^{-1}$ ($second^{-1}$, $minute^{-1}$ etc)	1 1 1 1
1a	iv	Types of catalyst deactivation: Poisons are substances present either in the reactants or produced by the reaction which lowers the activity of a catalyst. 1. Deactivation by fouling:- Rapid deactivation caused by physically depositing a substance which blocks the active sites of the catalyst. 2. Chemical Deactivation - Poisoning by reversible or irreversible chemisorption of substances on the active sites of the catalyst. 3. Deactivation by Thermal Degradation and Sintering: Deactivation caused by a change in the surface structure of the catalyst due to prolonged exposure of the catalyst to high temperature for a long time.	4
1b		Attempt any ONE of the following	06
1b	i	General procedure for analysis of complete rate equation by integral method	1 mark for each point



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The procedure for integral method of analysis is as follows :

1. In a constant volume system , the rate expression for the disappearance of reactant A will be of the following form
 $-r_A = -dC_A / dt = kf(c)$
2. Rate equation is rearranged as $-dC_A / f(c) = kdt$
 $f(c)$ involves the concentration of materials which may be expressed in terms of C_A
3. Above equation is integrated with appropriate limits

$$\int_{C_{A0}}^{C_A} \frac{dC_A}{f(c)} = k \int_0^t dt$$

4. The concentration function is proportional to time, so a plot of concentration vs time gives a straight line of slope k for this particular rate equation.
5. From experiment, determine the numerical value for the above integral and plot these at the corresponding time.
6. If the data fall on a reasonable straight line, then it may say that the particular rate equation being tested satisfactorily fits the data. If the data are being fitted by a curve, the rate equation and mechanism are rejected and another rate equation is tried.

Graph:



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1b	ii	<p>$T_1 = 400 \text{ K}$ $T_2 = 500 \text{ K}$ $k_2 = 10 k_1$ From Arrhenius law $\ln \frac{k_2}{k_1} = \frac{-E}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$ $\ln 10 = (-E / 1.987) * \left(\frac{1}{500} - \frac{1}{400} \right) = 2.52 * 10^{-4} E$ $E = 9137.2 \text{ cal}$</p>	<p>2 2 2</p>
2		Attempt any TWO of the following	16
2	a	<p>Arrhenius law The temperature dependence of the reaction rate constant k, is given by $k \propto e^{-\frac{E}{RT}}$ $k = k_0 e^{-\frac{E}{RT}}$ Where k_0 - frequency factor or pre exponential factor E - activation energy in J/ mol or cal/ mol R – universal gas constant T – temperature in Kelvin The activation energy is determined experimentally by carrying out the</p>	4



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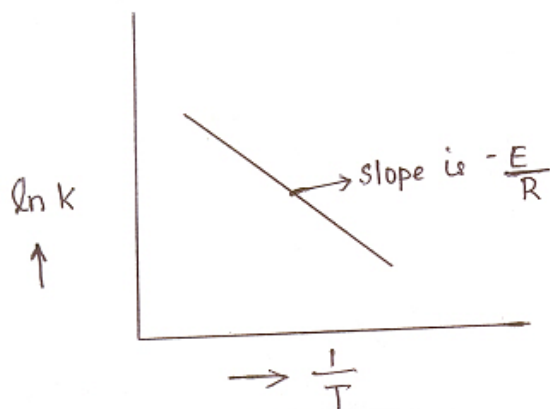
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reaction at different temperatures. A plot of $\ln k$ vs $\frac{1}{T}$ should give a straight line with slope equal to $\frac{-E}{R}$.



Alternatively, if the rate is known at two different temperatures T_1 and T_2 , then we can evaluate E with the help of equation

$$\ln \frac{k_2}{k_1} = \frac{-E}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$$

Lower the value of activation energy, higher will be the rate at which reaction will proceed as the considerable part of collisions between the molecules result in a reaction and higher the value of activation energy, lower will be the rate at which the reaction proceeds.

4

2 b

Given:

$$X_A = 0.70, t = 13 \text{ min}$$

For constant volume batch reactor,

$$t = CA_0 \int_0^{X_A} \frac{dX_A}{-r_A}$$

First order chemical reaction is taking place

$$-r_A = k.C_A = k.C_{A0}(1-X_A)$$



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		$t = C_{A0} \int_0^{X_A} \frac{dX_A}{k \cdot C_{A0} (1 - X_A)}$ <p>$-\ln(1 - X_A) = kt$ $-\ln(1-0.70) = k * 13$ $k = 0.0926 \text{ min}^{-1}$ For Plug flow reactor (constant –density system):</p> $\frac{V}{F_{A0}} = \int_0^{X_A} \frac{dX_A}{-r_A} = \frac{\tau}{C_{A0}}$ $\tau = C_{A0} \int_0^{X_A} \frac{dX_A}{k \cdot C_{A0} (1 - X_A)}$ $\tau = \int_0^{X_A} \frac{dX_A}{k \cdot (1 - X_A)}$ <p>Space time $\tau = \frac{1}{k}(-\ln(1-X_A)) = \frac{1}{0.0926}(-\ln(1 - 0.7)) = \mathbf{13 \text{ min}}$ Space velocity $s = 1/\tau = \mathbf{1/13 = 0.07692 \text{ min}^{-1}}$</p> <p>For MFR</p> $\frac{V}{F_{A0}} = \frac{\tau}{C_{A0}} = \frac{X_A}{-r_A}$ <p>Space time $\tau = \frac{C_{A0} \frac{X_A}{-r_A}}{0.7} = \frac{C_{A0} \frac{X_A}{k C_{A0} (1 - X_A)}}{0.7} = \frac{X_A}{K(1 - X_A)}$ $\frac{0.7}{0.0926(1-0.7)} = \mathbf{25.2 \text{ min}}$</p> <p>Space velocity $s = 1/\tau = \mathbf{0.039 \text{ min}^{-1}}$</p>	<p>2</p> <p>2</p> <p>1</p> <p>2</p> <p>1</p>
2	c	<p>Diagram of Fluidized bed reactor</p>	



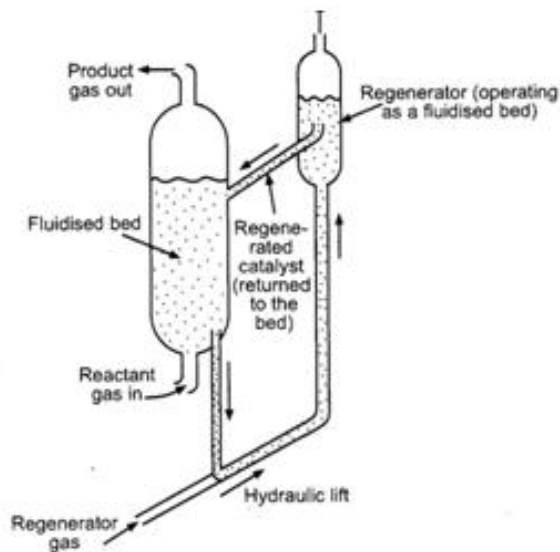
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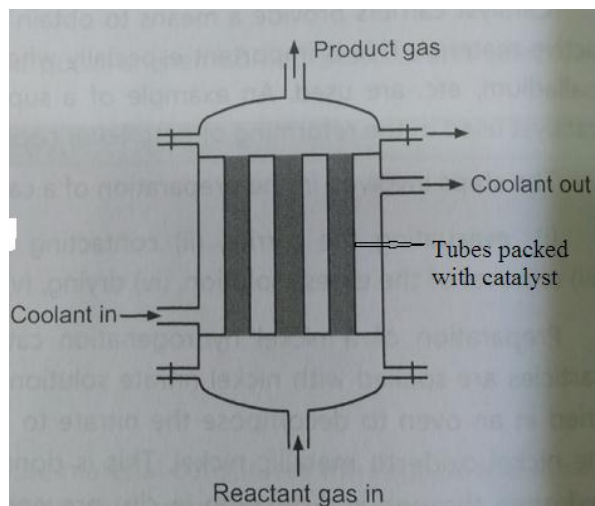
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Multitubular fixed bed reactor:



2 marks for diagram and
2 marks for labeling

2 marks for diagram and
2 marks for labeling

3		Attempt any FOUR of the following	16
3	a	Characteristics of chemical equilibrium: (i). It is the state when the rate of forward reaction is equal to the rate of	1 mark each for any 4



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		backward reaction. (ii) At chemical equilibrium, the net change in the concentration of reactants and products will be zero. (iii) Catalysts have no effect on the equilibrium point. (iv) Changes in the concentrations of either the products or reactants, temperature, volume, or pressure can offset the equilibrium point. (v) The equilibrium state can only be reached if the chemical reaction takes place in a closed system.	points															
3	b	Difference between order and molecularity of reaction.(4 points) <table border="1"><thead><tr><th>Sr.No.</th><th>Molecularity</th><th>Order of reaction</th></tr></thead><tbody><tr><td>1</td><td>Molecularity is the number of molecules, atoms or ions in a chemical reaction.</td><td>Order of reaction is the sum of exponents of the concentration terms involved in the rate equation.</td></tr><tr><td>2</td><td>Molecularity always have an integer value 1,2,3...</td><td>Order of reaction can have a fractional value.</td></tr><tr><td>3</td><td>Shows the elementary mechanism or separate steps of a complicated process</td><td>Shows the kinetic dependence of the rate on the concentration of the reactants.</td></tr><tr><td>4</td><td>Depending upon the value of molecularity, reaction can be</td><td>Depending upon the value of order, the reactions are termed as first order, second</td></tr></tbody></table>	Sr.No.	Molecularity	Order of reaction	1	Molecularity is the number of molecules, atoms or ions in a chemical reaction.	Order of reaction is the sum of exponents of the concentration terms involved in the rate equation.	2	Molecularity always have an integer value 1,2,3...	Order of reaction can have a fractional value.	3	Shows the elementary mechanism or separate steps of a complicated process	Shows the kinetic dependence of the rate on the concentration of the reactants.	4	Depending upon the value of molecularity, reaction can be	Depending upon the value of order, the reactions are termed as first order, second	1 mark each for any 4 points
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			unimolecular ,bimolecular etc.	order reactions		
		5	Molecularity is a theoretical quantity	Order of reaction is entirely an experimental value.		
3	c	<p>Relation between C_A & C_{A0} Consider the reaction $A \rightarrow R$ Let N_{A0} represent the number of moles of A present initially ($t = 0$). N_A represent the number of moles of A present at time t. X_A be the fractional conversion of A at time t Moles of A reacted at any time $t = N_{A0} X_A$ At time t, moles of A present $N_A = N_{A0} - N_{A0} X_A$ Divide throughout by V, $(N_A / V) = (N_{A0} / V) - (N_{A0} X_A / V)$ But concentration = moles / l Therefore $C_A = C_{A0} - C_{A0} X_A$; $C_A = C_{A0} (1 - X_A)$</p>			2	2
3	d	<p>Batch reaction/reactor: Advantages : 1.Simple in construction & operation 2. Low equipment cost 3. Gives highest conversion by leaving the reactants for longer periods in reactor. 4. Requires small instrumentation & less supporting equipment. Disadvantages:</p>			½ mark each	



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		1. High labor costs per unit volume of production. 2. Requires considerable time to empty, clean out & refill. 3. Poorer quality control of product. 4. Large scale production is difficult.	½ mark each
3	e	Characteristics of First order constant volume batch reaction: 1. Rate equation can be written as $-r_A = -\frac{dC_A}{dt} = KC_A$ Or $-r_A = C_{A0} \frac{dx_A}{dt} = k C_{A0} (1 - X_A)$ 2. Integrated form of rate expression is $-\ln(1-x_A) = kt$ or $-\ln(C_A/C_{A0}) = kt$ 3. Plot of $-\ln(1-x_A)$ Vs t gives a straight line passing through origin with slope k. 4. Plot of $-\ln(C_A/C_{A0})$ Vs t gives a straight line passing through origin with slope k. 5. k depends on the ratio of concentration or fractional conversion. 6. Unit of rate constant is time^{-1} and is independent of the units of concentration. 7. Half-life is independent of the initial concentration of the reactant.	1 mark each for any 4 points
4 a		Attempt any THREE of the following	12
4a	i	Integrated form of rate expression for zero order reaction Rate equation is $-r_A = -\frac{dC_A}{dt} = C_{A0} \frac{dx_A}{dt} = k$ In terms of fractional conversion $C_{A0} \frac{dx_A}{dt} = k$ Integrating between appropriate limits $C_{A0} \int_0^{x_A} dx_A = k \int_0^t dt$	4



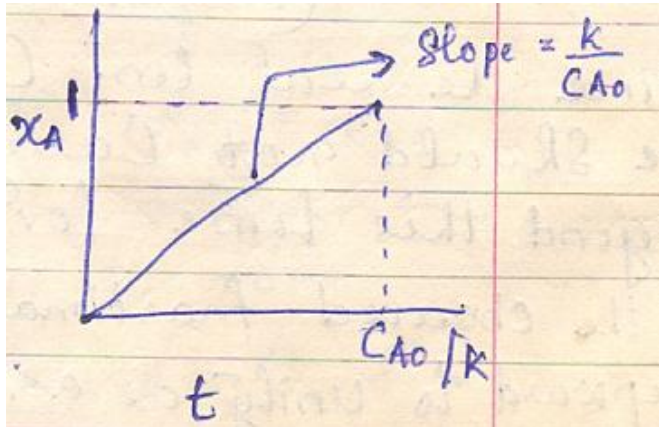
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		$C_{A0} X_A = kt \text{ for } t < \frac{C_{A0}}{k}$ 	
4a	ii	<p>Rate of a reaction: It is defined as change in the moles of any reactant / product of the reaction per unit time per unit volume of reacting fluid.</p> <p>Rate constant: Rate constant of a chemical reaction is a measure of the rate of the reaction when all the reactants are at unit concentration.</p> <p>Unit of rate constant for</p> <p>First order reaction</p> <p>General equation for unit of rate constant is $\text{time}^{-1}(\text{concentration})^{1-n}$</p> <p>Assume that concentration is given in mole/ liter and time in seconds</p> <p>For first order reaction $n=1$</p> <p>Therefore unit of rate constant is minute^{-1}</p> <p>Second order reaction:</p> <p>For second order reaction $n=2$</p> <p>Therefore unit of rate constant is $\text{minute}^{-1}(\text{mole/liter})^{-1} = \text{liter}/(\text{mole} \cdot \text{minute})$</p>	<p>1</p> <p>1</p> <p>1</p> <p>1</p>
4a	iii	Derivation for entropy change of an ideal gas for a constant volume process.:	



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		<p>From first law of thermodynamics, $dU = dQ - dW$</p> $dQ = dU + dW \dots\dots(i)$ <p>But $dQ = TdS \dots\dots(ii)$</p> $dW = PdV \dots\dots(iii)$ <p>For ideal gas $dU = n C_v dT \dots\dots (iv)$</p> <p>Substituting ii,iii and iv in i</p> $TdS = n C_v dT + PdV$ $dS = \frac{n C_v dT}{T} + \frac{PdV}{T}$ <p>For ideal gas $P = \frac{nRT}{V}$</p> <p>Substituting $dS = \frac{n C_v dT}{T} + \frac{nRdV}{V}$</p> <p>Integrating between limits</p> $\int_{S_1}^{S_2} dS = nC_v \int_{T_1}^{T_2} \frac{dT}{T} + nR \int_{V_1}^{V_2} \frac{dV}{V}$ $\Delta S = nC_v \ln \frac{T_2}{T_1} + nR \ln \frac{V_2}{V_1} \dots\dots(v)$ <p>For constant volume process , $v_1 = v_2$ and the equation becomes</p> $\Delta S = nC_v \ln \frac{T_2}{T_1}$	<p>2</p> <p>2</p>
4a	iv	<p>1. Catalyst:</p> <p>Any substance which alters the speed of a chemical reaction without itself undergoing any chemical change is known as catalyst.</p> <p>2.Promoters</p> <p>They are substances which do not act as catalyst but enhances the efficiency and life of the catalyst. It is a substance added during the preparation of a catalyst which improves the activity or selectivity or stabilizes the catalytic agent so as to increase its life.</p>	<p>1 mark each</p>



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		<p>3.Inhibitors</p> <p>It is the substance which decreases the performance of the catalyst. It lessens activity, stability or selectivity of a catalyst. It is useful for reducing the activity of a catalyst for an undesirable side reaction.</p> <p>3.Catalyst poison</p> <p>They are substances present either in the reactants or produced by the reaction which lowers the activity of the catalyst.</p>	
4b		Attempt any ONE of the following	06
4b	i	<p>For first order reaction, $-\ln(1-x_A) = kt$</p> <p>When $x_A = 0.5$ $-\ln(1-0.5) = kt_1$</p> $t_1 = \frac{0.693}{k} \quad - \quad (1)$ <p>When $x_A = 0.75$ $-\ln(1-0.75) = kt_2$</p> $t_2 = \frac{1.386}{k} \quad - \quad (2)$ <p>From equation (1) and (2) $t_2 = 2 t_1$</p> <p>Therefore the time required for 75% conversion is double the time required for 50% conversion.</p>	<p>3</p> <p>3</p>
4b	ii	<p>Relation between Gibb's free energy (ΔG^0) and equilibrium constant K_p</p> <p>Consider the reaction $aA + bB \rightarrow rR + sS$</p> <p>$\Delta G_{\text{reaction}} = \Delta G_{\text{product}} - \Delta G_{\text{reactant}}$</p> $= (r \mu_R + s \mu_S) - (a \mu_A + b \mu_B).$ <p>At equilibrium there is no Gibb's free energy change, $\Delta G = 0$</p> $(r \mu_R + s \mu_S) - (a \mu_A + b \mu_B) = 0$ $(r \mu_R + s \mu_S) = (a \mu_A + b \mu_B)$ <p>But $\mu_i = \mu_i^0 + RT \ln p_i$</p> <p>Therefore $r(\mu_R^0 + RT \ln p_R) + s(\mu_S^0 + RT \ln p_S) = a(\mu_A^0 + RT \ln p_A) +$</p>	2



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		$b(\mu_B^0 + RT \ln p_B)$ $RT \ln \left(\frac{p_R^r p_S^s}{p_A^a p_B^b} \right) = (a \mu_A^0 + b \mu_B^0) - (r \mu_R^0 + s \mu_S^0)$ $= -(\Delta G \text{ product} - \Delta G \text{ reactant})$ $= -\Delta G \text{ reaction.}$ $\ln \left(\frac{p_R^r p_S^s}{p_A^a p_B^b} \right) = \frac{-\Delta G \text{ reaction}}{RT} \quad \text{But } \left(\frac{p_R^r p_S^s}{p_A^a p_B^b} \right) = K_p$ <p>Therefore $\Delta G = -RT \ln K_p$</p>	2
5		Attempt any TWO of the following	16
5	a	<p>Performance equation of ideal batch reactor:</p> <p>In batch reactor, the composition is uniform throughout reaction zone at any instant of time.</p> <p>Taking material balance of the limiting reactant A over the whole reactor</p> <p>Rate of reactant A in = Rate of reactant A out + Rate of loss of reactant A due to chemical reaction + Rate of accumulation of reactant A within the reactor.</p> <p>In a batch reactor, no fluid enters or leaves the reaction mixture during the reaction. Therefore Rate of reactant A in = Rate of reactant A out = 0</p> <p>Material balance equation then becomes</p> <p>Rate of loss of reactant A due to chemical reaction = - Rate of accumulation of reactant A within the reactor----- (1)</p> <p>Rate of loss of reactant A due to chemical reaction = $-r_A V$</p> <p>Rate of accumulation of reactant A within the reactor = $\frac{dN_A}{dt} = -N_{A0} \frac{dX_A}{dt}$</p> <p>Substituting in equation (1)</p> $-r_A V = N_{A0} \frac{dX_A}{dt}$ <p>Rearranging and integrating</p>	1
			3



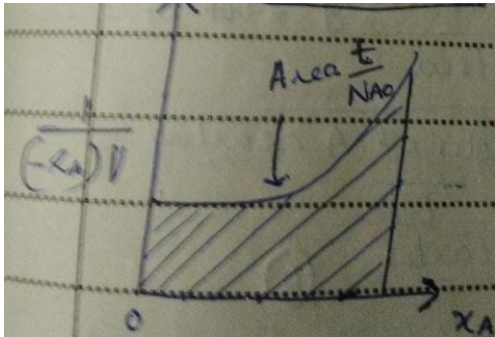
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	$\int_0^t dt = N_{A0} \int_0^{x_A} \frac{dx_A}{V(-r_A)}$ $t = N_{A0} \int_0^{x_A} \frac{dx_A}{V(-r_A)} \dots \dots \dots (2)$ <p>Equation (2) is the design equation for batch reactor, which indicates the time needed to achieve a conversion X_A. For either isothermal or non-isothermal operation, the terms rate $-r_A$ & volume V are retained under the integral sign because they both may change as the reaction proceeds.</p>  <p>For constant volume system, the equation becomes</p> $t = \frac{N_{A0}}{V} \int_0^{x_A} \frac{dx_A}{(-r_A)} = C_{A0} \int_0^{x_A} \frac{dx_A}{(-r_A)} = - \int_{C_{A0}}^{C_A} \frac{dC_A}{(-r_A)}$	<p>2</p> <p>2</p>
<p>5</p>	<p>b</p> <p>Integrated Rate Equation For second order reaction:</p> <p>(i) Definition: When the rate of reaction is directly proportional to the square of concentration of one reactant, it is called as second order reaction.</p> <p>(ii) Expression:</p> <p>$2A \rightarrow \text{product}$</p> <p>In terms of concentration</p> <p>Rate equation is $-r_A = -dC_A/dt = kC_A^2$</p> <p>Rearranging $-dC_A/C_A^2 = kdt$</p>	<p>2</p>



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On integration

$$Kt = (1/C_A - 1/C_{A0})$$

In terms of conversion

$$-r_A = -dC_A/dt = kC_A^2 \dots\dots(i)$$

$$\text{But } C_A = C_{A0}(1 - X_A) \text{ and } dC_A = -C_{A0} \cdot dX_A$$

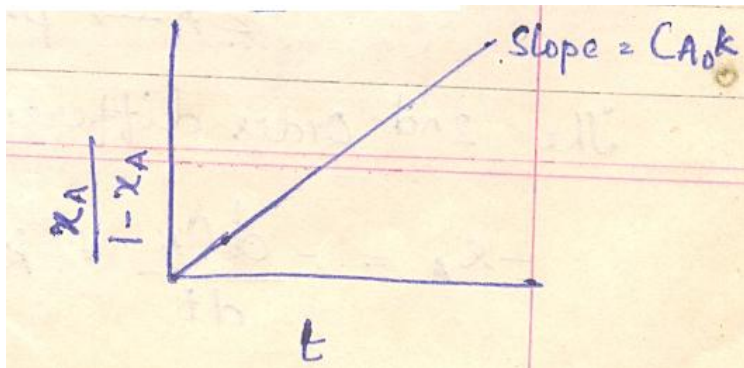
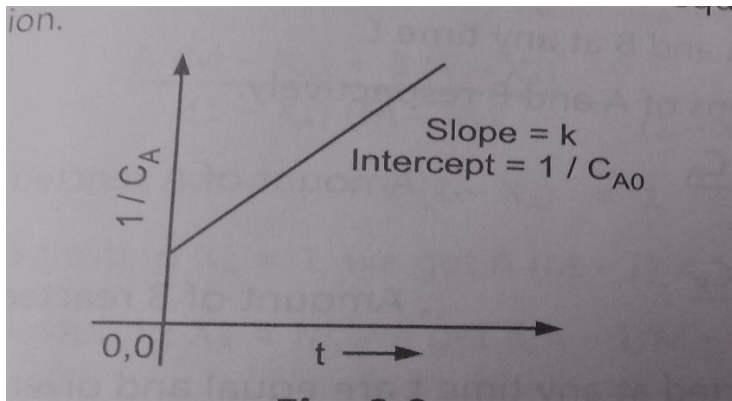
Equation (i) can be written as

$$C_{A0} (dX_A/dt) = k \cdot C_{A0}^2 (1 - X_A)^2$$

On integrating

$$1/C_{A0} \{ X_A/(1 - X_A) \} = kt$$

(iii) Graphical representation:



2

2

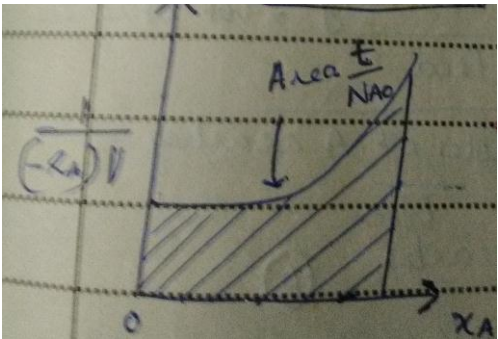
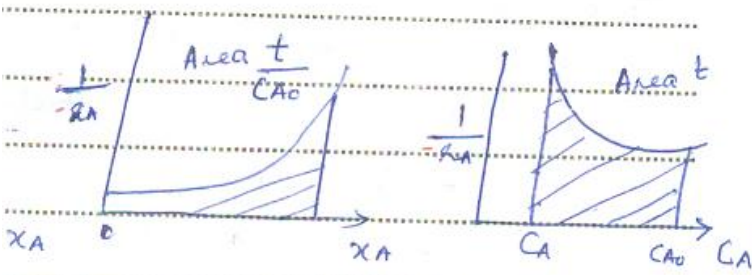


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		required, when catalyst regeneration has to be done on a continuous basis without shutting down the reactor.	
6		Attempt any FOUR of the following	16
6	a	<p>Graphical representation:</p> <p>Batch reactor</p> <p>The performance or design equation is</p> $t = N_{A0} \int_0^{x_A} \frac{dx_A}{V(-r_A)}$  <p style="text-align: center;">OR</p> <p>For constant volume system, the equation becomes</p> $t = \frac{N_{A0}}{V} \int_0^{x_A} \frac{dx_A}{(-r_A)} = C_{A0} \int_0^{x_A} \frac{dx_A}{(-r_A)} = - \int_{C_A}^{C_{A0}} \frac{dC_A}{(-r_A)}$  <p>Mixed flow reactor:</p> <p>The graphical representation of the performance equation in terms of fractional</p>	2



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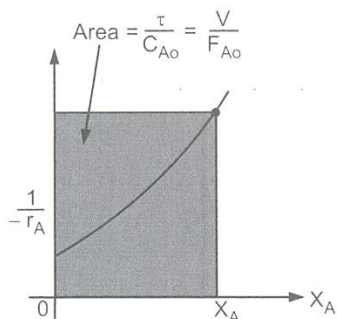
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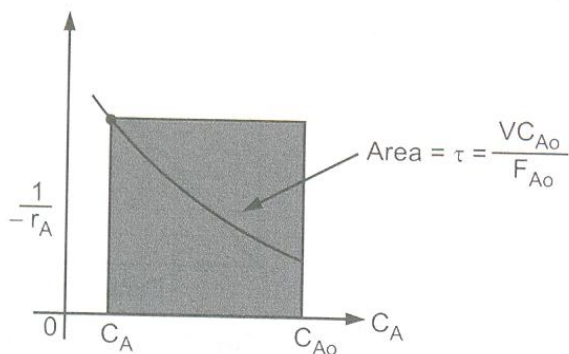
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conversion is as below



OR

The graphical representation of the performance equation in terms of concentration for constant density system is as below.



2

6 b **Comparison between elementary and non-elementary reaction (4 points):**

Sr no.	Elementary reactions	Non-elementary reactions
1	These are single steps reactions.	These are multistep reactions.
2	Simple in nature	Complex in nature
3	Order of each reactant is identical with	Not identical.

1 mark each
for any 4
points



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		stoichiometric coefficient of that species.			
		4	For these reactions, order must be an integer	Order may be an integer or fractional value.	
		5	If $2A \rightarrow R$, the rate law is $-r_A = kC_A^2$	For non-elementary reaction $2B \rightarrow S$, the rate law may be $-r_B = kC_B^\alpha$ Where $\alpha \neq 2$	
		6	Ex $C_2H_5OH + CH_3COOH \rightarrow CH_3COOC_2H_5 + H_2O$	Ex. $H_2 + Br_2 \rightarrow 2HBr$	
6	c	<p>Methods of catalyst Preparation:</p> <ol style="list-style-type: none"> 1. Precipitation 2. Gel formation 3. Simple mixing 4. Impregnation method <p>1.Precipitation method : This method produces catalyst in porous form.It consists of adding a precipitating agent to the solution of the desired component. The precipitation is followed by washing,drying, calcinations & activation(or pretreatment) Eg. Magnesium oxide catalyst is prepared by this method. It is prepared by precipitating $MgCO_3$ from magnesium nitrate solution by adding sodium carbonate.The magnesium carbonate precipitate is washed, dried & calcined to</p>			<p>2</p> <p>2</p>



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		obtain magnesium oxide.	
6	d	<p>Definition:</p> <p>(i) Thermodynamics: It is the branch of science which deals with all forms of energy and the inter conversion of the different forms of energy. OR It is the branch of science which deals with the relations between heat and other forms of energy accompanying physical and chemical processes.</p> <p>(ii) Enthalpy: It is a measure of the total heat content of the system OR It is the total energy possessed by the system .It is the sum of the internal energy and the flow energy.</p> <p>(iii) Chemical Potential: It is defined as the change in free energy of a substance when one mole of it is added to such a large quantity of the system that there is no appreciable change in overall composition of the system at constant temperature & pressure</p> <p>(iv) Chemical Kinetics: It is the study of the rates at which chemical reactions occur and effect of parameters like temperature, pressure and concentrations of reactant on the rate of reaction.</p>	1 mark each
6	e	<p>Relation between K_p and K_c (Derivation)</p> <p>Consider the reaction $aA + bB + \dots \rightarrow rR + sS \dots$</p> $K_c = (C_R^r \cdot C_S^s) / (C_A^a \cdot C_B^b)$ <p>For ideal gas $C_i = p_i / RT$</p> <p>Where R is the ideal gas constant</p> <p>T the absolute temperature in K</p> <p>P is the pressure in atm</p> <p>Therefore $K_c = \{ (p_R / RT)^r \cdot (p_S / RT)^s \} / \{ (p_A / RT)^a \cdot (p_B / RT)^b \}$</p>	2



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		$= (p_R^r \cdot p_S^s) / (p_A^a \cdot p_B^b) \cdot (1 / RT)^{(r+s+\dots-(a+b+\dots))}$ <p>Ie $K_c = K_p \cdot (1 / RT)^{\Delta n}$ where $K_p = (p_R^r \cdot p_S^s) / (p_A^a \cdot p_B^b)$</p> <p>And $\Delta n = (r + s + \dots - (a + b + \dots))$ is the difference in the number of moles of product and reactant</p> <p>Or $K_p = K_c \times (RT)^{\Delta n}$</p>	2
6	f	<p>Types of intermediates in non- chain reaction:</p> <p>1. Free radicals. Free atoms or larger fragments of stable molecules which contain one or more unpaired electrons are called free radicals. The unpaired electron is designated by a dot in the chemical symbol for the substance.</p> <p>Eg. $\dot{C}H_3$</p> <p>$C_2\dot{H}_5$</p> <p>2. Ions and polar substances. Electrically charged atoms, molecules or fragments of molecules such as Na^+, OH^-, NH_4^+ are called ions. They may act as intermediates in reaction.</p> <p>3. Molecules: Consider the consecutive reaction</p> <p>$A \rightarrow R \rightarrow S$</p> <p>This is a multiple reaction. If the product R is highly reactive, its concentration in the reaction mixture can become too small to measure. In such a situation, R is not observed and can be considered to be a reactive intermediate.</p> <p>4. Transition complexes. The collision between reactant molecules result in a wide distribution of energies among the individual molecules. This can result in strained bonds, unstable form of molecules or unstable association of molecules which can then either decompose to give products or by further collision return to molecules in the normal state. Such unstable forms are called transition complexes.</p>	1 mark each