(Autonomous) (ISO/IEC - 27001 - 2005 Certified)

WINTER-19 EXAMINATION Model Answer

Subject title: Chemical Reaction Engineering

Subject code

17562

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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.





WINTER-19 EXAMINATION <u>Model Answer</u>

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Q No.		Answer		Marking	
1 a	Attempt any THREE of the following			schem	
1a i	Differe	nce between elementary and non-ele	ementary reaction (4 points):	1 mark each	
	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	Not identical.		
		with stoichiometric coefficient of			
		that species			
	4	For these reactions, order must be	Order may be an		
		an integer	integer or fractional		
			value.		
	5	If $2A \rightarrow R$, the rate law is	For non-elementary		
		$-r_A = kC_A^2$	reaction $2B \rightarrow S$,the		
			rate law may be		
			$-r_{\rm B} = {\rm k}C_{\rm B}^{\alpha}$		
			Where $\propto \neq 2$		
	6	$Ex C_2H_5OH + CH_3COOH \rightarrow$	Ex. $H_2 + Br_2 \rightarrow 2HBr$		
		$CH_3COOC_2H_5 + H_2O$			

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1a ii	Enthalpy:	1
	Enthalpy is the total heat content of a body.	
	Mathematical equation:	1
	H = U + PV	
	Gibb's free energy: It is the energy actually available to do useful work. It	1
	predicts the feasibility and equilibrium conditions for chemical reactions at	
	constant temperature and pressure.	
	Mathematical equation:	
	G = H-TS	1
1a iii	Half-life :	
	Half-life period is the time required to reduce the concentration of the reactant	2
	to half of its original value.	
	$t_{1/2} = 240$ seconds	
	For the first order reaction: $t_{1/2} = 0.693 / k$	
	$k = 0.693 / t_{\frac{1}{2}} = 0.693 / 240$	2
	Rate constant $k = 2.89 * 10-3 s^{-1}$	
1a iv	Fluidized bed reactor with catalyst regenerator:	4
	Product gas out Fluidised bed Fluidised bed Regene- rated catalyst bed Begenerator Hydraulic lift	

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1b ii Activation energy: It is the minimum energy that the reactant molecules must acquire before 2 reaction takes place to give the product. $T_1 = 10^0 C = 283 K$ $T_2 = 30^0 C = 303 K$ 2 $K_1 = 1.6 * 10^{-3} S^{-1}$ $K_2 = 1.625 * 10^{-2} S^{-1}$ From Arrhenius law $\ln \frac{k_2}{k_1} = \frac{-E}{R} (\frac{1}{T_2} - \frac{1}{T_1}) =$ 1 $\ln \frac{0.01625}{0.0016} = (-E / 8.314) x (\frac{1}{303} - \frac{1}{283})$ 2 2 Activation energy E= 82630.28 J /mole = 19673.87 cal/ mol 1 1 $\ln k_1 = \ln k_0 - \frac{E}{RT_1}$ 1 0.0016 = \ln k_0 - (82630.28 / (8.314* 283))) 2 $\ln k_0 = 2868129911$ Frequency factor $k_0 = 2.858* 10^{12}$ 2	t title:	Chemical Reaction Engineering Subject code 17	562
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Consider the reversible reaction $A + B \leftrightarrow AB$, k_1 is the rate constant for		the rate of decomposition of the complex is the same for all reactions and	d is 2
		given by kT / h where k is Boltzmann constant and h is Planck constant.	
forward reaction and k_2 is the rate constant for backward reaction		Consider the reversible reaction A + B \leftrightarrow AB, k ₁ is the rate constant	for
		forward reaction and k_2 is the rate constant for backward reaction	



Subject title: Chemical Reaction Engineering Subject code 17562 Page 6 of 25 k3 According to transition theory, $A + B \leftrightarrow AB^* \rightarrow AB$ k_4 **k**5 $K_c = k_3 / k_4 = C_{AB} * / C_A C_B$ $K_5 = kT/h$ $r_{AB,forward}$ = (concentration of activated complex). (rate of decomposition of activated complex) $= C_{AB}^{*} . (kT / h)$ 3 $= (kT / h) \cdot K_c \cdot C_A \cdot C_B$ From thermodynamics, $\Delta G = \Delta H - T\Delta S = -RT \ln K_c$ $\ln K_c = -(\Delta G / RT)$ $K_c = e^{-(\Delta G / RT)} = e^{-(\Delta H / RT) + \Delta S / R}$ $r_{AB,forward} \ = (kT \ / \ h \).C_A. \ C_B \ . \ e^{-(\Delta H \ / \ RT) \ + \ \Delta S \ / \ R}$ = a constant. T. $e^{-(\Delta H/RT)} C_A$. $C_B = k C_A$. C_B where $k = a \text{ constant} \cdot T \cdot e^{-(\Delta H/RT)}$ $e^{\Delta S/R}$ is less temperature sensitive compared to the other terms so that it can be taken as constant. For forward reaction, $k_1 \alpha T e^{-(\Delta H_1/RT)}$ 3 For backward reaction, $k_2 \alpha T e^{-(\Delta H / RT)}$ For relating ΔH and Arrhenius activation energy, analogy from thermodynamics is used. $E = \Delta H$ - RT for liquids and solids $E = \Delta H$ - (molecularity – 1) RT for gases The difference between E and ΔH is small and of the order RT. Hence transition theory predicts that K α T e^{-(E/RT)}



t title:	Ch	emical Reaction Engineering	Subject code	17562	2
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2 b	5	Derivation of performance equa	tion of mixed flow reactor in whi	ch first	
		order reaction is taking place:			
		In MFR, the composition of the re	actants is uniform throughout the re	actor.	
		Taking material balance of reactar	at A over the reactor as a whole,		
		Rate of input of A to the reactor	= Rate of output of A from the r	eactor +	
		Rate of disappearance of A due to	chemical reaction + Rate of accum	nulation	
		of A within the reactor.			
		For mixed flow reactor at steady s	tate the last term is zero. Therefore	the	
		material balance equation become	s		
		Rate of input of A to the reactor	=Rate of output of A from the read	ctor +	1
		Rate of disappearance of A due to	chemical reaction	(i)	
		Let, $F_{A0} =$ Molar feed rate to the	reactor		
		V = Volume of reactor			
		$C_{A0} = Molar \text{ concentration } c$	of A in stream entering the reactor		
		(moles/volume)			
		$v_0 = Volumetric flow rate(v)$	volume/time)		
		X_A = Fractional conversion	of A		
		$F_{A0} = C_{A0.} v_0$			
		Input of A to the reactor in moles	$/ \text{ time} = F_{A0.}$		
		Disappearance of A due chemical	reaction in moles / time $=$ (-r _A) .	1	
		Output of A from the reactor in	moles / time $= F_A$		
		Substituting in (i)			
		$F_{A0} = F_{A+}(-r_A) . V$	(ii)		
		But $F_A = F_{A0} (1 - X_A) = F_{A0} - 1$	$F_{A0.} X_A$		4
		Equation (ii) becomes $F_{A0} = F_{A0}$	- $F_{A0.} X_{A} + (-r_A) . V$		

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Subject title: Chemical Reaction Engineering Subject code 17562 Page 8 of 25 $F_{A0} X_A = (-r_A) .V$ Rearranging, we get $\frac{V}{F_{A0}} = \frac{X_A}{-r_A} = \frac{\tau}{C_{A0}}$ For constant volume system $\frac{V}{F_{A0}} = \frac{X_A}{-r_A} = \frac{\tau}{C_{A0}} = \frac{C_{A0-CA}}{CA0(-r_A)}$ Where X_A and (-r_A) are evaluated at the exit conditions, which are same as conditions prevailing within reactor (ex .composition, temperature) For first order reaction $-\mathbf{r}_{A} = \mathbf{k}\mathbf{C}_{A} = \mathbf{k}\mathbf{C}_{Ao}$ (1- \mathbf{x}_{A}) 1 $\frac{V}{F_{A0}} = \frac{\tau}{C_{A0}} = \frac{X_A}{KC_{A0}(1 - X_A)} = \frac{C_{A0 - CA}}{CA0(kC_A)}$ The graphical representation of the performance equation in terms of fractional conversion is as below Area = $\frac{\tau}{C_{Ao}} = \frac{V}{F_{Ao}}$ $\frac{1}{-r_A}$ ► X_A 0 X_{Δ} The graphical representation of the performance equation in terms of 2 concentration for constant density system is as below.

ect titl	le: Cl	nemical Reaction Engineering Subject code 17562	2
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		$\frac{1}{-r_A}$ C_A $\frac{1}{C_A}$ C_A $\frac{VC_{AO}}{C_A}$	
2	c	Auto catalysis:	
		A reaction in which one of the products of the reaction acts as a catalyst is	2
		called as an autocatalytic reactions.	
		Example: Oxidation of a solution of oxalic acid by an acidified solution of	
		KMnO ₄ .	
		Promoters:	
		They are substances which do not act as catalyst but enhances the efficiency	2
		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.	
		Inhibitors:	
		It is the substance which decreases the performance of the catalyst. It	2
		lessens activity, stability or selectivity of a catalyst. It is useful for reducing the	
		activity of a catalyst for an undesirable side reaction.	
		Accelerators:	
		A material added to the reactant stream to improve the performance of a	2
		catalyst is known as accelerators.	
3	1	Attempt any FOUR of the following	16
3	a	Relation between equilibrium conversion and thermodynamic equilibrium	
		constant(Derivation)	

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	Reaction is $A \leftrightarrow R$				
	Let 1 mole of A be present initially	у.			
	x_A mole of A reacts at equilib	orium			
	P be the total pressure.				
		Α	R	Total moles	
	Moles present initially	1			
	Moles reacted / produced at equilibrium	XA	X _A		
	Moles present at equilibrium	1- x _A	X _A	1	2
	Mole fraction	1- x _A	XA		
	Partial pressure	P(1-	P x _A		
		x _A)			
	$\mathbf{K}_{p} = \frac{Px_{A}}{P(1-x_{A})} = \frac{x_{A}}{1-x_{A}}$		1		
	$\mathbf{K}_{\mathbf{p}} (1 - \mathbf{x}_{\mathbf{A}}) = \mathbf{x}_{\mathbf{A}}$				
	$K_p - K_p x_A = x_A$				
	$K_{p} = x_{A} \left(1 + K_{p} \right)$				2
	$x_A = \frac{Kp}{1+Kp}$				
3 b	CA0'=0.1 mol/l t _{1/2} '= 1152 min				
	CA0'' = 0.2 mol/l $t_{1/2}$ '' = 568 min				
	$t_{1/2} = \frac{C_{AO^{1-n}}}{k(n-1)} [(2^{n-1}) - 1]$				1
	$(t_{1/2}' / t_{1/2}'') = (C_{A0}' / C_{A0}'')^{1-n}$				1
	Taking log and rearranging				
	$n = 1 - (\log (t_{1/2}'/ t_{1/2}'') / \log (C_{A0}'/ C_{A0}''))$)			
	$n = 1 - (\log (1152/5 \ 68)) (\log (0.1/0.2))$				3
	n=1+1.02=2.02 Order of the reaction	n is 2			5



			Page 11 of
3	c	$C_p(ice) = 9.0145 \text{ cal / g mole K}$	
		$C_p(water) = 18 \text{ cal } / \text{ g mole K}$	
		Molar enthalpy of fusion = 1437.1 cal / g mole	
		1. Entropy change when 2 moles of ice is heated from -10° C to 0° C	1
		$\Delta S_1 = nC_{p(ice)} \int_{T_1}^{T_2} d \ln T = nC_{p(ice)} \ln \frac{T_2}{T_1} = 2* 9.0145* \ln (273/263)$	
		= 0.6728 cal / K	
		2. Entropy change when 2 molse of ice at 0° C is converted to water at	1
		$0^{\circ}C$	1
		$\Delta S_2 = n\Delta H$ fusion / T _{fusion} = 2* 1437.1 / 273 = 10.5282 cal / k	
		3. Entropy change when 2 moles of water is heated from 0° C to 10° C	1
		$\Delta S_3 = nC_{p(water)} \int_{T_1}^{T_2} d\ln T = 2 *18 * \ln (283 / 273) = 1.295 \text{ cal / k}$	1
		Total entropy change $\Delta S = \Delta S_1 + \Delta S_2 + \Delta S_3 = 12.496$ cal /K	
3	d	Factors affecting the rate of a chemical reaction (any four) :	1 mark eac
		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.	
		1. rate of heat transfer	
		2. Catalyst	
		3. Nature of reactants	
		4. Surface area available.	
		5. Intensity of light if reaction is light sensitive.	



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3 e		omparison between	fluidized bed and pacl	ked(fixed) bed reactor (any 1 mark each	
	fo	our):				
			Fluidized bed	Fixed bed		
		(i) Recovery	Catalyst loss is there,	Catalyst loss is not		
		units	so recovery units are	there, so recovery		
			required	units are not required		
		(ii) Catalyst	Easily done	Difficult		
		regeneration				
		(iii)	Can maintain	Difficult to maintain		
		isothermal	isothermal conditions			
		condition:				
		(iv) size of	Can use small size of	Cannot use very small		
		catalyst	catalyst	size of catalyst		
				because of plugging		
				and high pressure		
				drop		
		(v) Type of	Flow is complex	Plug flow		
		flow				
4 a	A	ttempt any THREE of	of the following		12	
4a i	S	Second order reaction of the form $A + B \rightarrow product$				
	Si	nce $C_{A0} = C_{B0} = 0.0$	3 mol/l, the reaction red	uces to the form		
	2.	$A \rightarrow Product$				
	F	or second order reaction	on of the form $2A \rightarrow Proc$	luct :		
		$k = \frac{1}{t} \left[\frac{1}{C_A} - \frac{1}{C_{A0}} \right]$			2	
	k	= 6.5 l / (mol minute)				

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Subject title: Chemical Reaction Engineering Subject code 17562 Page 13 of 25 $t = 10 \min$ $6.5 = \frac{1}{10} \left[\frac{1}{C_A} - \frac{1}{0.03} \right]$ $C_A = 0.01017 \text{ mol} / 1$ 2 Proportion of ester hydrolyzed = $\frac{C_{AO} - C_A}{C_{AO}} = \frac{0.03 - 0.01017}{0.03} = 0.661 = 66.1\%$ 4a ii **Desired properties of catalyst (any four)** ¹/₂ mark 1. Porosity each 2. Large surface area 3. High selectivity 4. High activity 5. Low kindling point 6. High accessibility 7. Long life and regenerability 8. Adequate thermal / mechanical strength in reaction conditions 9. Non toxic and cheap **Definition (any two)** Activity is a measure of the accelerating effect that the catalyst has on the rate of given reaction. Activity of catalyst is measured by finding the ratio between 1 mark each the rate constant of a catalysed and uncatalysed reaction. Selectivity or specificity of a catalyst refers to the property of catalyst to speed up the main reaction in the presence of several side reactions. Porosity is defined as the ratio of volume of voids to the total volume of catalyst. **Kindling point** of a substance is the lowest temperature at which it spontaneously ignites in normal atmosphere without an external source of ignition, such as a flame or spark.



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4a	iii	Graphical representation of integrated rate equation for second order	
		reaction $2A \rightarrow$ Product:	
		In terms of concentration:	
		ICA ICA ICASE E	2
		In terms of conversion:	
		Slope = CAok	2
4a	iv	Feasibility of a chemical reaction from Gibbs free energy change:	
		At chemical equilibrium $\Delta G^0 = 0$. For a chemical reaction at equilibrium at a	4
		given temperature & pressure, the free energy must be minimum.	
		If $\Delta G^0 < 0$ i.e. it is negative, the reaction can take place spontaneously (reaction	
		is possible under the given set of conditions). For spontaneous reaction, there	
		should be decrease in Gibb's free energy change.	
		If ΔG^0 is positive, the reaction cannot take place under the given conditions.	
4b	1	Attempt any ONE of the following	06
4b	i	From Arrhenius law , $k = k_0 e^{-E/RT}$	

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	$E_1 = 17982 \text{ cal / mol}$ $E_2 = 11980 \text{ cal / mol}$	
	$T = 25^{0}C = 298K$	
	For Un catalyzed reaction, $k_1 = k_0 e^{-E_1/RT}$ and	
	For catalyzed reaction $k_2 = k_0 e^{-\frac{E_2}{2}/RT}$	2
	$\ln k_1 = \ln \operatorname{ko-} \frac{E_1}{RT} \dots (1)$	
	$\ln k_2 = \ln k_0 - \frac{E_2}{PT} \dots (2)$	
	(2) - (1) gives $\ln \frac{k_2}{k_1} = \frac{E_1 - E_2}{RT} = \frac{17982 - 11980}{1.987 \cdot 298} = 10.136$	2
	$\frac{k_2}{k_1}$ =25,244	2
	$k_2 = 25,244 \ k_1$	Δ.
	ie Catalyzed reaction is 25,244 times faster than un catalyzed reaction	
4b ii	Relation between K _p , K _y and K _c	
	Consider the reaction $aA + bB + \dots \rightarrow rR + sS \dots$	
	$K_{c} = (C_{R}^{r} \cdot C_{S}^{s}) / (C_{A}^{a} \cdot C_{B}^{b})$	
	For ideal gas $C_i = p_i / RT$	
	Therefore $K_c = \{(p_R / RT)^r . (p_S / RT)^s\} / \{(p_A / RT)^a . (p_B / RT)^b\}$ = $(p_R^r . p_S^s) / (p_A^a . p_B^b) . (1 / RT)^{(r + s + (a+b=))}$	
	R is the ideal gas constant	
	T the absolute temperature in K	
	P is the pressure in atm	3
	$ieK_{c} = K_{p}$. $(1 / RT)^{\Delta n}$ where $K_{p} = (p_{R}^{r} \cdot p_{S}^{s}) / (p_{A}^{a} \cdot p_{B}^{b})$	
	$\Delta n = (r + s + (a + b +))$ is the difference in the number of moles of	
	product and reactant	
	Or $\mathbf{K}_{\mathbf{p}} = \mathbf{K}_{\mathbf{c}} \times (\mathbf{RT}) \Delta^{\mathbf{n}}$	
	$K_{p} = (p_{R}^{r} \cdot p_{S}^{s}) / (p_{A}^{a} \cdot p_{B}^{b})$	





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		But $p_A = P \cdot y_A$ Where p_A - partial pressure of A, P- total pressure	
		y_A – mole fraction of A.	
		$K_{p} = (p_{R}^{r} \cdot p_{S}^{s}) / (p_{A}^{a} \cdot p_{B}^{b})$	
		$= \{ (Py_R)^r . (Py_S)^s \} / \{ (Py_A)^a . (Py_B)^b \}$	3
		$= (y_{R}^{r} \cdot y_{S}^{s}) / (y_{A}^{a} \cdot y_{B}^{b}) \cdot P^{(r+s+)-(a+b+))}$	
		$K_p = K_y \cdot P^{\Delta n}$ where $K_y = (y_R^r \cdot y_S^s) / (y_A^a \cdot y_B^b)$ and	
		$\Delta n = (r + s +) - (a + b +)$ is the difference in the number of moles of	of
		product and reactant	
		$\mathbf{K}_{c} = \mathbf{K}_{p} (1 / \mathbf{RT})^{\Delta n} = \mathbf{K}_{y} (\mathbf{P} / \mathbf{RT})^{\Delta n}$	
5	1	Attempt any TWO of the following	16
5	a	Integrated rate expression for constant volume irreversible unimolec	cular
		first order reaction (derivation):	
		Consider the reaction $A \rightarrow B$	
		In terms of concentration	
		The rate equation is $-\mathbf{r}_A = -\mathbf{d}\mathbf{C}_A / \mathbf{d}\mathbf{t} = \mathbf{k}\mathbf{C}_A(1)$	2
		Rearranging - $\frac{dC_A}{C_A}$ = k dt	
		Integrating between appropriate limits	
		$-\int_{C_{AO}}^{C_A} \frac{dC_A}{c_A} = k \int_0^t dt$	
		$-(\ln C_A / C_{A0}) = kt$	
		Slope = k	2

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Subject title: Chemical Reaction Engineering Subject code 17562 Page 17 of 25 In terms of conversion $C_A = C_{A0}(1 - X_A)$ On differentiation it gives $dC_A = -C_{A0}dX_A$ $-dC_A = C_{A0}dX_A$ Substituting the values of dC_A and C_A in eq.1 $C_{A0}\frac{dX_A}{dt} = k.C_{A0}(1-X_A)$ Rearranging and integrating we get $\int_0^{X_A} \frac{dX_A}{1 - X_A} = k \int_0^t dt$ 2 $-ln(1-X_A) = kt$ 3 lope k 2 - Kn(F-XA -1 Data: 5 b $F_{AO} = 10 mol / s$ $X_{\rm A} = 0.6$ 0.2 0.6 0.8 0 0.4 X_A 0.182 0.1 0.0357 0.143 0.0667 $-r_A$ 1 5.5 7 28 $1/(-r_A)$ 10 15 For a mixed flow reactor





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Subject title: Chemical Reaction Engineering Subject code 17562 Page 19 of 25 $\frac{V}{F_{40}} = 9 (l.sec/mol)$ $V = 9 * F_{A0} = 9 * 10 = 90$ lit. Volume of CSTR = 90 lit. 2 For a plug flow reactor $\frac{V}{F_{A0}}$ is the area under the curve from $X_A = 0$ to $X_A =$ 0.6 Area under the curve = 21.5 cm^2 $\frac{V}{F_{AD}} = Area X(Scale on X - axis)X(Scale on Y - axis)$ $\frac{V}{F_{A0}} = 21.5 \text{ cm}^2 \text{ X} \frac{5(l.sec/mol)}{2 \text{ cm}} \text{ X} \frac{0.1}{1 \text{ cm}}$ $\frac{V}{F_{A0}} = 5.375$ V = 5.375 X F_{A0} = 5.375 X 10 = 53.75 lit Volume of PFR = 53.75 lit. 2 Volume of PFR(53.75 lit.) is less than the volume of CSTR (90 lit.) for the same conversion.($X_A = 0.6$) 5 **Design equation of batch reactor** с In batch reactor, the composition is uniform throughout reaction zone at any instant of time. 2 Taking material balance of a limiting reactant A ,over the reactor as a whole 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. In a batch reactor, no fluid enters or leaves the reaction mixture during the

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	$\frac{1}{1} \frac{1}{r_A} \frac{1}{r$	Area = 1 . C _A C _{NO}	
6	Attempt any FOUR of the following		16
6	a Method of feeding when PFR's are co	onnected in parallel	
	Consider PFRs are connected as shown For the PFRs connected in parallel, the plug flow reactor of volume equal to to feed is distributed in such a manner to same composition. Thus for reactors in each parallel line. Any other method of Ie $\left(\frac{V}{F}\right)$ for branch $A = \left(\frac{V}{F}\right)$ for branch $\left(\frac{F_{01}}{F_{02}}\right) = \left(\frac{V_1}{V_2}\right)$ For example: If $V_1 = 80$ lit & $V_2 = 40$ lit	whole system can be treated as otal volume of the individual un that fluid stream which meet parallel, V/F or τ must be the feeding is inefficient.	have the 2

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		$\left(\frac{F_{01}}{F_{02}}\right) = \left(\frac{V_1}{V_2}\right) = \frac{80}{40} = 2$		2	
		$F_{o1} = 2F_{o2}$			
		Total feed $F = F_{o1} + F_{o2} = 2F_{o2} + F_{o2} = 3F_{o2}$			
		Fraction of feed fed to branch A = $F_{o1} / F = 2F_{o2} / 3 F_{o2} = 2/3$			
		Fraction of feed fed to branch B = $F_{o2} / F = F_{o2} / 3 F_{o2} = 1/3$			
6	b	Entropy change of an ideal gas:			
		From first law of thermodynamics, $dU = dQ - dW$			
		$dQ = dU + dW \dots(i)$			
		But $dQ = TdS$ (ii)			
		dW = PdV(iii)			
		For ideal gas dU= $n C_v dT$ (iv)			
		Substituting ii,iii and iv in i			
		$TdS = n C_v dT + PdV$			
		$dS = \frac{n Cv dT}{T} + \frac{P dV}{T}$			
		For ideal gas $P = \frac{nRT}{V}$			
		Substituting dS = $\frac{n CvdT}{T} + \frac{nRdV}{V}$			
		Integrating between limits			
		$\int_{S_1}^{S_2} dS = nC_v \int_{T_1}^{T_2} \frac{dT}{T} + nR \int_{V_1}^{V_2} \frac{dV}{V}$		2	
		$\Delta S = nC_v ln \frac{T_2}{T_1} + nRln \frac{V_2}{V_1} \dots \dots (v)$			
		For ideal gas $PV = RT$			
		$\frac{P_2 V_2}{P_1 V_1} = \frac{T_2}{T_1}$			
		Therefore $\frac{V_2}{V_1} = \frac{T_2 P_1}{T_1 P_2}$ (vi)			
		Integrating between limits $\int_{S_1}^{S_2} dS = nC_v \int_{T_1}^{T_2} \frac{dT}{T} + nR \int_{V_1}^{V_2} \frac{dV}{V}$ $\Delta S = nC_v ln \frac{T_2}{T_1} + nRln \frac{V_2}{V_1} \dots (v)$ For ideal gas PV = RT $\frac{P_2 V_2}{P_1 V_1} = \frac{T_2}{T_1}$		2	

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		Also $Cp - Cv = R$ (vii)		2
		Substituting vi and vii in v		
		$\Delta S = n(C_p - R) ln \frac{T_2}{T_1} + nR ln \frac{T_2 P_1}{T_1 P_2}$		
		$\Delta S = nC_p ln \frac{T_2}{T_1} + nR ln \frac{P_1}{P_2}$		
6	c	Chain reaction:		
		In Chain reaction, the intermediate is formed in the first reaction cal		
		initiation step. It then combines with the reactant to form product an	d more	
		intermediates in the chain propagation step. Occasionally these inter	mediates	
		are destroyed in chain termination step.		2
		Reactants \rightarrow Intermediate* Initiation step		
		$Intermediate^* + Reactant \rightarrow Intermediate^* + Product Propaga$	ation step	
		Intermediate*→Product Termina	tion step.	
		Non-chain reaction:		
		In non chain reaction, the intermediate is formed in the first reaction	n and then	2
		disappears as it reacts further to give products.		
		Reactants \rightarrow (Intermediates)*		
		$(Intermediates)^* \rightarrow Products$		
6	d	Integrated form of rate expression for zero order reaction		
		Rate equation is $-\mathbf{r}_{A} = -\frac{dC_{A}}{dt} = C_{A0}\frac{d_{xA}}{dt} = \mathbf{k}$		
		In terms of concentration		
		$-\frac{dC_A}{dt} = \mathbf{k}$		
		Integrating between appropriate limits		2
		$\int_{CA_0}^{CA} - dCA = k \int_0^t dt$		-



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2. Low equipment cost			
3. Gives highest conversion by leaving the reactants for longer pe	riods in		
reactor.			
4. Requires small instrumentation & less supporting equipment.			
Disadvantages (2 each):		1 mark ea	nch
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.			