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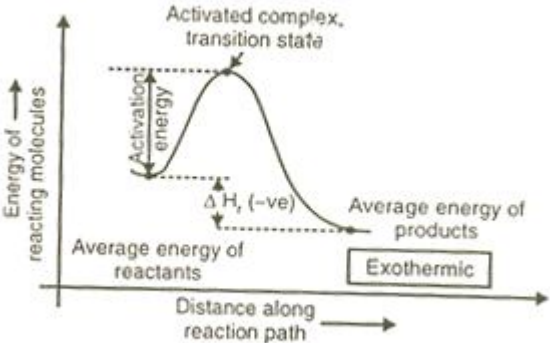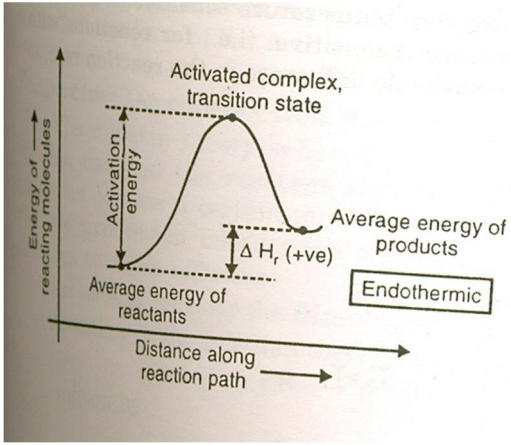
SUMMER-13 EXAMINATION
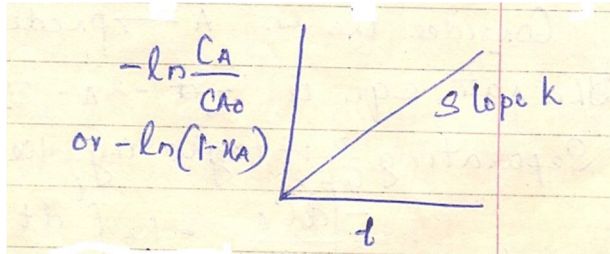
Model Answer

Subject & code : CRE (12206)

Important instructions to examiners :

1. The answers should be examined by keywords 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 given more importance.
4. While assessing figures, examiner may give credit for principal components indicated in a 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 answer and model answer.
6. In case of some questions credit may be given by judgment of relevant answer based on candidates understanding.

Q No:	Answer	Mark	Total marks
1A. a	**Enthalpy**: Enthalpy(H) is a measure of the total heat content of the substance or system.	1	4
	Expression: $H = U + PV$	1	
	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.	1	
	Expression: $dS = d_{Qreversible} / T$	1	
1A. b	**Rate law**: Rate law is defined as the number of moles of reactant reacted or product produced in unit volume in unit time.	2	4
	Expression: For component i, $r_i = (1/ V) dN_i / dt$ where V is the volume of reactor and dN_i / dt is the rate of change of component i	2	

1A. c	**Fractional conversion x_A:** Fractional conversion x_A of reactant A is defined as the fraction of A that is converted into product.	2		4
	Equation: $C_A = C_{A0}(1-x_A)$ or $N_A = N_{A0}(1-x_A)$	2		
1A. d	**Material balance equation for a batch reactor:**			4
	Material balance equation for any reactor is	2		
	(rate of reactant in) = (rate of reactant out) + (rate of reactant loss due to chemical reaction) + (rate of accumulation of reactant within the reactor)			
	For batch reactor, rate of reactant in = rate of reactant out = 0			
	Therefore material balance equation for a batch reactor is	2		
	Rate of reactant loss due to chemical reaction = -(rate of accumulation of reactant within the reactor)			
1B. a	**Relation between K_p, K_c and K_y**	3		6
	Consider the reaction $aA + bB + \ldots \rightarrow rR + sS\ldots\ldots$			
	$K_c = (C_R^r \cdot C_S^s) / (C_A^a \cdot C_B^b)$			
	For ideal gas $C_i = p_i / RT$			
	Therefore $K_c = \{(p_R / RT)^r \cdot (p_S / RT)^s\} / \{ (p_A / RT)^a \cdot (p_B / RT)^b\}$			
	$= (p_R^r \cdot p_S^s) / (p_A^a \cdot p_B^b) \cdot (1 / RT)^{(r + s + \ldots -(a+b=\ldots))}$			
	ie $K_c = K_p \cdot (1 / RT)^{\Delta n}$ where $K_p = (p_R^r \cdot p_S^s) / (p_A^a \cdot p_B^b)$			
	$\Delta n = (r + s + \ldots-(a + b +\ldots))$ is the difference in the number of moles of product and reactant			
	$p_A = P \cdot y_A$ Where p_A - partial pressure of A, P- total pressure			
	y_A – mole fraction of A.			
	$K_p = (p_R^r \cdot p_S^s) / (p_A^a \cdot p_B^b)$	3		
	$= \{(Py_R)^r \cdot (Py_S)^s\} / \{ (Py_A)^a \cdot (Py_B)^b\}$			
	$= (y_R^r \cdot y_S^s) / (y_A^a \cdot y_B^b) \cdot P^{(r + s + \ldots -(a+b=\ldots))}$			
	$K_p = K_y \cdot P^{\Delta n}$ where $K_y = (y_R^r \cdot y_S^s) / (y_A^a \cdot y_B^b)$			
	$K_c = K_p \cdot (1 / RT)^{\Delta n} = K_y \cdot (P / RT)^{\Delta n}$			
1B. b	**Activation energy :** Activation energy is the minimum energy that the reactants must acquire before reaction takes place to give the product. It can be considered as a potential energy barrier. Only those molecules that	2		6

have sufficient energy to reach the top of the barrier and form activated complex react. Smaller the activation energy(low barrier), greater will be the number of activated molecules and faster will be the rate of reaction.

Graphical representation

For exothermic reaction

	2	

For endothermic reaction

2

| 2.a | **Temperature dependency of rate constant from transition state theory**: Reactants combine to form unstable intermediates called activated complex which then decompose spontaneously into products. An equilibrium exists between the concentration of reactants and activated complex at all times and the rate of decomposition of the complex is the same for all reactions and is given by kT / h where k is | 2 | 8 |

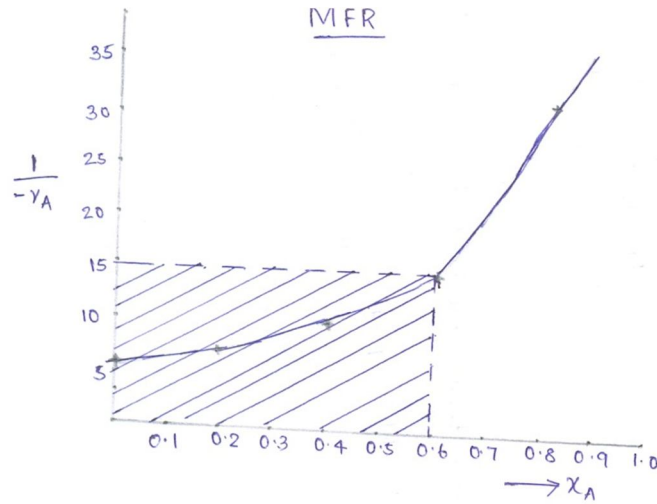|			
	Boltzmann constant and h is Planck constant		
	Consider the reversible reaction $A + B \leftrightarrow AB$, k_1 is the rate constant for forward reaction and k_2 is the rate constant for backward reaction	2	
	$$k_3$$ According to transition theory, $A + B \leftrightarrow AB^* \rightarrow AB$ $$k_4 \qquad k_5$$ $K_c = k_3 / k_4 = C_{AB}* / C_A . C_B$ $K_5 = kT/h$ $r_{AB,forward}$ = (concentration of activated complex) . (rate of decomposition of activated complex) $\qquad = C_{AB}* . (kT / h)$ $\qquad = (kT / h) . K_c . C_A . C_B$ From thermodynamics, $\Delta G = \Delta H - T\Delta S = - RT \ln K_c$ $$\ln K_c = - (\Delta G / RT)$$ $$K_c = e^{-(\Delta G / RT)} = e^{-(\Delta H / RT) + \Delta S / R}$$ $r_{AB,forward} = (kT / h) . C_A . C_B . e^{-(\Delta H / RT) + \Delta S / R}$ $\qquad = $ a constant $. T. e^{-(\Delta H / RT)} C_A . C_B = K C_A . C_B$ $e^{\Delta S / R}$ is less temperature sensitive compared to the other terms so that it can be taken as constant. For forward reaction, $k_1 \alpha T e^{-(\Delta H_1 / RT)}$ For backward reaction, $k_2 \alpha T e^{-(\Delta H_2 / RT)}$ For relating ΔH and Arrhenius activation energy, analogy from thermodynamics is used.	2	
	$E = \Delta H - RT$ 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 $K \alpha T e^{-(E / RT)}$	2	
2.b	**First order reaction:** First order reaction is the reaction whose order of reaction is one.ie the concentration of the reactant is raised to unity in the rate equation.	2	8
	Rate equation: $-r_A = kC_A$	1	

	Derivation:	2	
	Consider the reaction $A \rightarrow B$		

The rate equation is $-r_A = -dC_A / dt = kC_A$....(1)

Separating and integrating, $-\int_{C_{A0}}^{C_A} (dC_A / C_A) = k \int_0^t dt$

$-(\ln C_A / C_{A0}) = kt$

In terms of conversion: $C_A = C_{A0}(1-x_A)$ 2

$dC_A = - C_{A0}dx_A$

Substituting in (1) and rearranging and integrating

$\int_{x_{A0}}^{x_A} (dx_A / (1-x_A)) = k \int_0^t dt$

$-\ln(1-x_A) = kt$

1

2.c	$x_A = 0.6$		8
	$F_{A0} = 10$ mol/s		

x_A	$-r_A$	$1/-r_A$
0	0.182	5.49
0.2	0.143	6.99
0.4	0.1	10
0.6	0.0667	14.99

1

0.8	0.0317	31.55

For MFR

$V/ F_{A0} = x_A / -r_A$

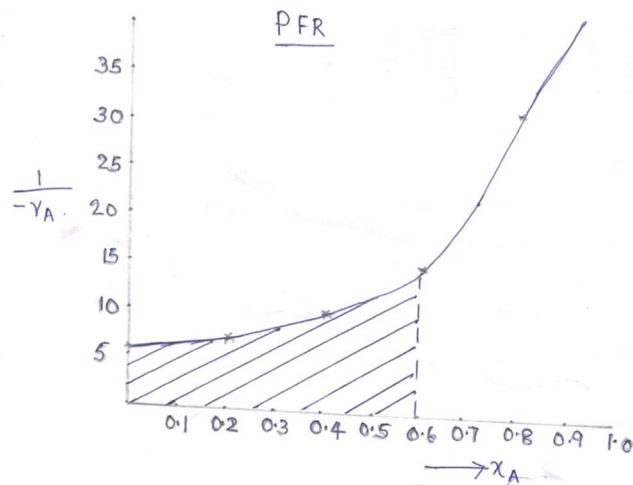Plot a graph with x_A on x axis and $1/-r_A$ on y axis.

Area from the graph = 9
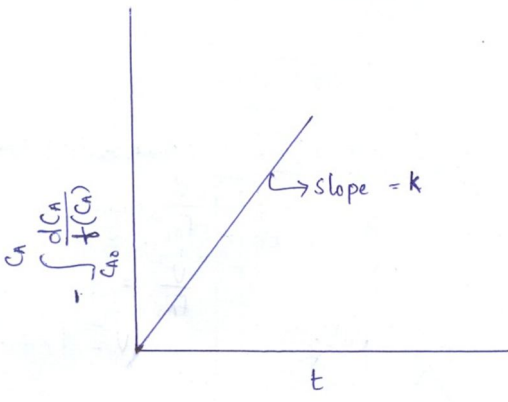
$V/ F_{A0} = 9$

$V = 9 . 10 = 90$ litres

For PFR

$$V/ F_{A0} = \int_{0}^{x_A} (dx_A / -r_A)$$

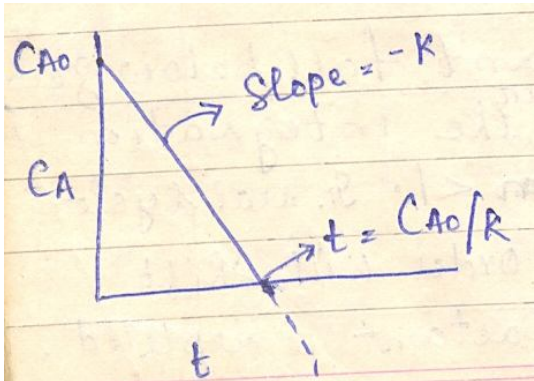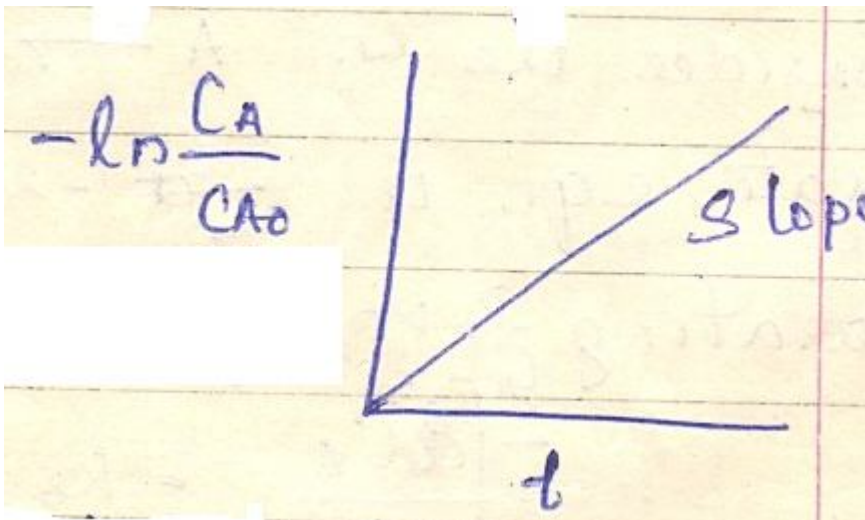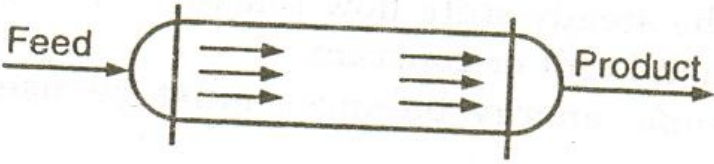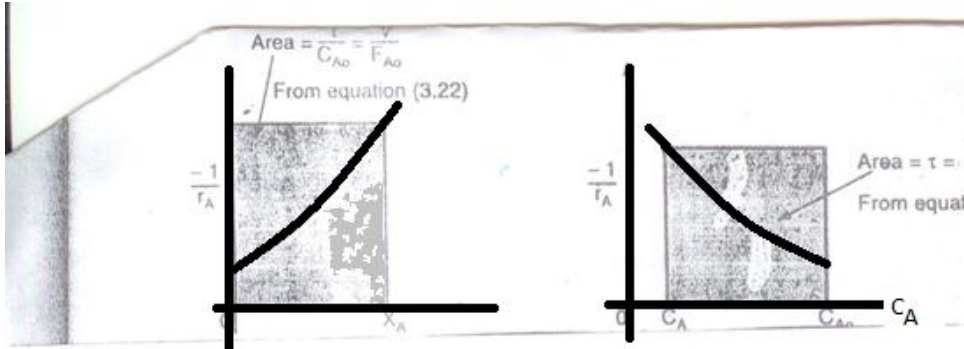|			
	Area under the curve between 0 and 0.6 = 5.315		
	$V/ F_{A0} = 5.315$		
	$V = 5.315 \times 10 = 53.15$ litres		
	Volume of MFR required for 60% conversion is greater than that of PFR.	1	
3.a	**Integral method of analysis** : The procedure for integral method of analysis is as follows : 1. In a 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 $C_A \qquad\qquad t$ $-\int (dC_A / f(c)) = k \int dt$ $C_{A0} \qquad\qquad 0$ 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 said 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:	3	4

			1	
3.b	$K_1 = 1.10^{-3}$ min^{-1} $K_2 = 2.10^{-3}$ min^{-1} $T_1 = 27^0$c = 300K $T_2 = 37^0$c = 310K $R = 1.987$ cal / gmole K $\ln(k_1/k_2) = -(E/R)(1/T_1 - 1/T_2)$ $E = 12809.2$ calories	1 2 1	4
3.c	**First law of Thermodynamics :** First law of thermodynamics states that energy can neither be created nor be destroyed, it can only be converted from one form to another. Although energy assumes many forms , the total quantity of energy is constant and when energy disappears in one form , it appears simultaneously in other forms. $\Delta U = Q - W$ **Second law of Thermodynamics :** Second law of Thermodynamics can be stated in two ways. 1. Entropy of an isolated system tends to increase and reaches a maximum value. 2. Heat cannot pass from a cold body to a hot body. Mechanical work can be completely converted to heat, but heat cannot be completely converter to work without making some changes	2 2	4

	either in the system or in the surrounding. $dS= dQ_{reversible} / T$			
3.d	**Space time** : It is the time required to process one reactor volume of feed measured at specified condition.	1		4
	Unit : unit of time i.e. minute, hour .	1		
	Space velocity : It is the number of reactor volume of feed at specified condition which can be treated in unit time.	1		
	Unit : time^{-1} i.e. minute^{-1} , hour^{-1}	1		
3.e	**Regeneration of catalyst** : Regaining the activity of poisoned catalyst by different method is known as regeneration of catalyst.	1		4
	Methods for regeneration catalyst : 1. Volatile poison may be removed from the catalyst surface by passing current of pure gas or liquid or by raising the temperature. 2. Coke deposited on the catalyst is removed by roasting the coke by atmospheric oxygen at 550-700 ^{0}c . 3. Metallic catalyst like nickel are regenerated by washing with alcohol or acid and other solvents. Irreversibly poisoned catalyst like platinum on silica support , silver and vanadium pentoxide are regenerated by extracting platinum, silver and vanadium from them using acids and alkalies. 4. Magnetic methods are also used for regenerating the activity of catalyst. 5. Metals concentrate on the surface of cracking catalyst and they can be removed by the abrasion of surface bed. 6. Alumino silicate cracking catalyst gets poisoned due to the deposition of metal on them. The poison is converted to a form which is highly volatile or readily soluble in water and the catalyst is treated with aqueous solution of organic acid , alkalies and gases.	1 mark each for any 3 points		

4A.a	$\Delta G = - RT \ln K$			2	4
	Where ΔG - Gibb's free energy			2	
	$\quad\quad$ R – Universal gas constant				
	$\quad\quad$ T- Temperature in K				
	$\quad\quad$ K- equilibrium constant				

4A.b		Arrhenius theory	Collision theory		2 marks each	4
		1. $k \propto e^{-(E/RT)}$	$k \propto T^{1/2} e^{-(E/RT)}$			
		2. Holds good for unimolecular and bimolecular reactions.	Holds good for bimolecular reactions but fails with unimolecular reactions			

4A.c	1) **Zero order reaction**.	2	4
	2) **First order reaction**.	2	

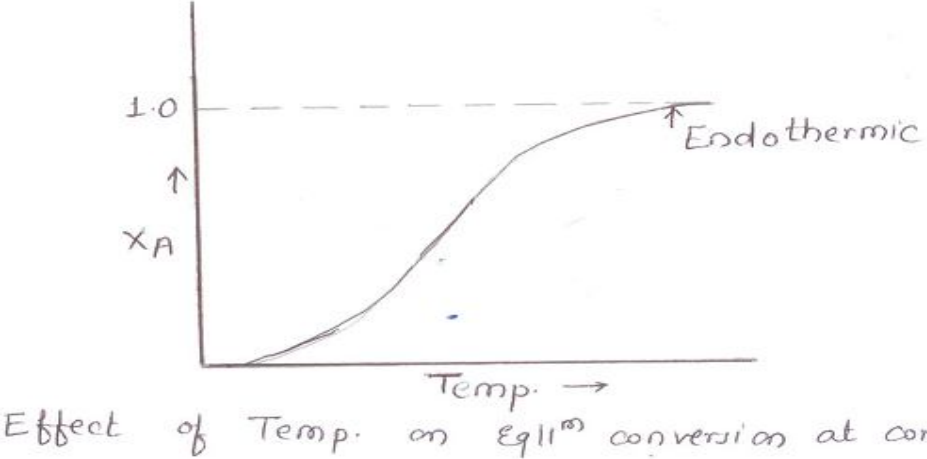|				
4A.d	**Activity** : It is a measure of the accelerating effect that the catalyst has on the rate of given reaction. Activity of catalyst is measured by finding the ratio between the rate constant of a catalysed and uncatalysed reaction.	2		4
	Selectivity : Selectivity or specificity of a catalyst refers to the property of catalyst to speed up the main reaction in the presence of several side reactions.	2		
4B. i	For first order reaction , $-\ln(1-x_A) = kt$…..(1)	2		6
	First Case:	2		
	$x_A = 0.4$			
	t= 5 minutes			
	solving, $k = 0.1021 \text{min}^{-1}$			
	Second Case:	2		
	$x_A = 0.75$			
	Substituting in eqn (1) , t = 13.57 minutes			
	Time required to reach 75% conversion is 13.57 minutes.			
4B.ii	**i.** **CSTR** :			
	Diagram :			6
		1		
	In CSTR the contents are well stirred and uniform through out. The exit stream from the reactor has the same composition as the fluid within the reactor.			
	Advantages :	½ mark each for any two points		
	1. Good temperature control			

2. Possible to operate under isothermal condition even when the reaction is exothermic.

3. Low cost of construction .

4. Long residence time due to its larger volume.

5. Uniform mixing.

Disadvantages :

1. Large reactor is required for high conversion.

2. Not suitable for high pressure reaction.

3. Low area of heat transfer per unit volume and low heat transfer coefficient.

i) **PFR** :

Diagram :

In PFR , the flow of fluid through the reactor is orderly with no element of fluid overtaking or mixing with any other element ahead or behind .

Advantages :

1. Easy to maintain as there are no moving parts.

2. Gives highest conversion per unit volume of reactor.

3. Suitable for high pressure reaction.

4. Rate of heat transfer per unit volume of reaction mixture is high and has high heat transfer coefficient.

Disadvantages :

1. Difficult to control temperature within the reactor.

2. Hotspots can be formed for exothermic reactions.

½ mark each for any two points

1

½ mark each for any two points

½ mark each for any two points

5.a	Performance equation of mixed flow reactor: Here the composition of the reactants is uniform throughout the reactor. Taking material balance of reactant A over the reactor as a whole, Input of a to reactor = Output of A from reactor + Disappearance of A due to chemical reaction + Accumulation of A within the reactor.	1	8
	For mixed flow reactor at steady state the last term is zero. Input of a to reactor = Output of A from reactor + Disappearance of A due to chemical reaction	1	
	Let, F_{A0} = Molar feed rate to the reactor V = Volume of reactor C_{A0} = Molar concentration of A in stream entering the reactor (moles/volume) v_0 = Volumetric flow rate(volume/time) X_A = Fractional conversion of A $F_{A0} = C_{A0}. v_0$ The molar rate at which A is entering in the reactor = $F_{A0}. X_A$ $F_{A0}. X_A$ = Moles of A fed / time x Moles of A reacted/ moles of A fed Moles of A reacted/ time = $F_{A0}. X_A$ Molar flow rate of A leaving the reactor = F_A	1	
	Molar flow rate Molar rate at which Molar rate at which At which A - A is consumed = A leaves the reactor is fed to reactor F_{A0} - $F_{A0}. X_A$ = F_A Output of A from reactor = $F_A = F_{A0} (1- X_A)$ Rate Disappearance of A due to chemical reaction = $(-r_A) .V$ $F_{A0} = F_{A0} (1- X_A) + (-r_A) .V$ Rearranging, we get	1	
	$$\frac{V}{F_{A0}} = \frac{X_A}{-r_A}$$ $$\frac{V}{F_{A0}} = \frac{\tau}{C_{A0}} = \frac{X_A}{(-r_A)}$$		
	$$\tau = \frac{1}{s} = \frac{V}{v_0} = \frac{V.C_{A0}}{F_{A0}} = \frac{C_{A0}}{-r_A}$$ Where X_A and $(-r_A)$ are evaluated at the exit conditions,which are same as conditions prevailing within reactor(ex.composition,temp.) The above equation is the performance equation for a mixed flow reactor. Applicable for any value of ε. For first order reaction, $-r_A = kC_A$	2	

	Therefore $\tau = VC_{A0} / F_{A0} = C_{A0} / kC_A$	2	
5.b	**Catalyst promoters**: A substance which do not act as a catalyst but enhance the efficiency of a catalyst & prolong it's life is called as promoter. Promoters are present in small amounts & are added during preparation of catalysts. **Ex**: Molybdenum(Mo) acts as apromoter in ammonia synthesis by the Haber's process,in which iron is used as a catalyst. **Accelerators**: Materials that are added to the reactant stream to improve performance of a catalyst are called as accelerators. They function opposite to poisons. **Ex**: In dehydrogenation of butene to butadiene using Fe as catalyst ,steam is added to butene feed.The added steam to reactor reduces the coke formation & increases the yield of butadiene. **Inhibitors**: A substance which decreases the rate of a reaction(instead of increasing it) is called as an inhibitors or negative catalyst. Inhibitors are useful for reducing the activity of catalyst for an undesirable side reaction. **Ex**: Silver supported on alumina is an excellent catalyst for oxidation of ethylene to ethylene oxide. However at the same reaction condition, complete oxidation to CO_2 & water also occurs ,so that the selectivity of ethylene oxide is poor.it has been found that adding halogen compound to the catalyst inhibits the complete oxidation of ethylene & results in satisfactory selectivity.	2 1 1 1 2 1	8
5.c	**Van't Hoff Equation**: The van'thoff isotherm: Let us consider the following chemical reaction $aA + bB \rightleftharpoons rR + sS$		8

The free energy of mixture of a moles of A & b moles of B in terms of chemical potential(at constant temperature,pressure& composition)is
  G (reactants) = $a\mu_A + b\mu_B$ and
  G(products)   = $r\mu_R + s\mu_S$
The free energy (ΔG) accompanying the above reaction at constant temperature & pressure is
ΔG = G(products)   - G (reactants)
	1	

$\Delta G = (r\mu_R + s\mu_S) – (a\mu_A + b\mu_B)$ eq1 The chemical potential μ of any constituent of a mixture is given by $\mu = \mu^0 + RT \ln a$ μ^0= chemical potential of a substance in standard state of unit activity &a is the activity of the substance in mixture under consideration. On substituting chemical potential in above equation 1, $\Delta G = (r\mu^0_R + s\mu^0_S) – (a\mu^0_A + b\mu^0_B) + RT(r \ln a_R + s \ln a_S - a \ln a_A – b \ln a_B)$	1	
As $\Delta G^0 = (r\mu^0_R + s\mu^0_S) – (a\mu^0_A + b\mu^0_B)$ $\Delta G = \Delta G^0 + RT\ln(a^r_R . a^s_S / a^a_A .a^b_B)$ eq2 The free energy change accompanying a chemical reaction under equilibrium conditions must be equal to zero. ΔG =0 Eq 2 becomes	1	
$0 = \Delta G^0 + RT\ln(a^r_R . a^s_S / a^a_A .a^b_B)_e$ e indicates activity at equilibrium $\Delta G^0 = - RT \ln(a^r_R . a^s_S / a^a_A .a^b_B)$ $\Delta G^0 = -RT \ln K$ eq3 Eq3 relates std. free energy change of the reaction at a specified temp.T to the thermodynamic equilibrium constant. For gases behaving ideally ,use of partial pressure & so chemical potential of any substance is given by $\mu = \mu^0 + RT \ln p$ Therefore $\Delta G^0 = -RT \ln Kp$ Van't Hoff isotherm Van't Hoff isotherm relates Gibb's free energy &equilibrium constant.	1	
The equilibrium constant may increase/ decrease with the temperature.The dependence of temp. of equilibrium constant at constant pressure is quantitatively given by the Van't Hoff isobar which clearly shows that it depends upon astandard enthalpy Change. $$\frac{d\ln K}{dT} = \frac{\Delta H°}{RT2}$$ The effect of temperature on equilibrium constant may be determined by differentiation of the Van't Hoff isotherm. Van't Hoff isotherm is $$\Delta G° = -RT\ln K$$ $$\ln K = -\Delta G°/RT$$ Differentiating with T yields	1	

$$\frac{dlnK}{dT} = \frac{-1}{R}\frac{d(\Delta G°/T)}{dT}$$

We have dG = VdP – SdT

At constant pressuredP= 0

dG = -SdT

$d(dG^0) = -\Delta S^0 dT$

$\Delta S^0 = - d(dG^0) / dT$

As $\Delta G^0 = \Delta H^0 - T\Delta S^0$

Substituting value for ΔS^0, we get

$dG^0 = \Delta H^0 + T\, d(\Delta G^0)/dT$

Rearranging we get,

$-\Delta H^0 = T\, d(\Delta G^0)/dT - \Delta G^0$

Dividing both the sides by T^2

$-\Delta H^0 / T^2 = T\, d(\Delta G^0)/dT - \Delta G^0/ T^2$

The RHS of above equation is obtained by differentiating $\Delta G^0/T$ wrt T.

$$\frac{d(\Delta G°/T)}{dT} = \frac{T\left(\frac{d(\Delta G°)}{dT}\right) - \Delta G°}{T^2}$$

As $\frac{d(\Delta G°/T)}{dT} = -\frac{\Delta H°}{T^2}$

Combining above equations we get

$$-R\frac{(dlnK)}{dT} = \frac{-\Delta H°}{T^2}$$

$\frac{dln\,K}{dT} = \frac{\Delta H^0}{RT^2}$

ΔH^0 is the standard enthalpy change for a reaction at a constant temperature i.e. the standard heat of reaction.

$\Delta H^0 = \Delta H^0{}_R = (\Sigma\Delta H^0{}_f)$products $- (\Sigma\Delta H^0{}_f)$ reactants

For the homogeneous gaseous phase reaction, Van't Hoff isobar given by the above equation takes form as

$$\frac{d\,lnKp}{dT} = \frac{\Delta H°}{RT^2}$$

When ΔH^0 is +ve, d lnKp/dT > zero &Kp(T) is a increasing function.
ΔH^0 is -ve, d lnKp/dT < zero &Kp(T) is a decreasing function.

6.a	Given :t $_{1/2}$ = 240 seconds		4
	For the first order reaction: t $_{1/2}$ = 0.693 / k		
	k = 0.693 / t $_{1/2}$	1	
	k = 0.693/ 240	1	
	k = 2.89 * 10-3 s^{-1}	1	
	k = 2.89 * 10-3 * 60	1	
	k = 0.1732 min^{-1}		
6.b	Given:		4
	E = 75000 cal/mol		
	T$_1$ = 500 ^{0}C = 773 ^{0}K		

	$T_2 = 650\,0C = 923\,^0K$
	$R = 1.987$ cal/mol.K
	Let k_1 & k_2 be the rate constants at temp T_1 & T_2 respectively.
	  $\ln(k_2/k_1) = E/R\,(1/T_1 - 1/T_2)$
	$\ln(k_2/k_1) = 75000/1.987(1/773 - 1/923)$
	$\ln(k_2/k_1) = 7.951$
	  $k_2/k_1 = 2838$
	  $k_2 = 2838\,k_1$
	At 650 ^{0}C,the decomposition is faster by a factor 2838 than at 500 ^{0}C.
		2
		
		2	

6.c	**Variation of reaction with temperature at constant pressure for Endothermic reactions:** Endothermic reactions are those chemical reactions where the heats of products are greater than the heats of reactants. The magnitude of equilibrium constant determines the extent to which a reaction can proceed under given set of conditions. A large value of Kp indicates that the concentration of products in mixture at equilibrium are larger to that of so that reaction favours the formation of products. In this case the extent of reaction is high. The equation which helps to find out the variation of the equilibrium constant ,and hence equilibrium conversion with temperature is $$R\ln\frac{Kp_2}{Kp_1} = \Delta\alpha\ln\frac{T_2}{T_1} + \frac{\Delta\beta(T_{2-T_1})}{2} + \frac{\Delta\gamma}{3}(T_2^2 - T_1^2)$$ $$+ \left[-\Delta H_0^\circ + \Delta\alpha T_0 + \frac{\Delta\beta}{2}\cdot T_0^2 + \frac{\Delta\gamma}{3}\cdot T_o^3\right]\cdot\left[\frac{1}{T_2} - \frac{1}{T_1}\right]$$ For endothermic reactions , equilibrium conversion rises with an increase in temperature. (Kp increases with increase in temperature. As Kp increases ,rate of chemical reaction also increases.) 	2 1 1	4

| 6.d |

For the PFRs connected in parallel, the whole system can be treated as a single plug flow reactor of volume equal to total volume of the individual units if the feed is distributed in such a manner that fluid stream which meet have the same composition. Thus for reactors in parallel, V/F must be the same for each parallel line.

Let us consider from above figure that volume of reactor 1 in branch A V_1 & of reactor 2 in branch B is V_2.

For branch A $\quad \frac{V_1}{F0_1} = \int_0^{x_1} \frac{dX}{(-r)}$

For branch B $\quad \frac{V_2}{F0_2} = \int_0^{x_2} \frac{dX}{(-r)}$

For the PFRs in parallel, the ratio V/F must be identical if the conversion is to be the same in each branch.

$\qquad x1 = x2 = x$

$\frac{V_1}{F0_1} = \frac{V_2}{Fo_2}$

$$FO = FO_1 + FO_2$$

Therefore Feed flow to first branch should be multiple of $\frac{V_2}{F_{01}} \cdot V_1$

For example:

If V1 = 80 lit & V2 = 40 lit

$\frac{F_A}{F_B} = \frac{V_A}{V_B} = \frac{80}{40} = 2$

Therefore 2/3 rd of feed must be fed to branch A. | 1

1

1

1 | 4 |
| 6.e | Given:

$X_A = 0.70$, t = 13 min

For batch reactor with first order chemical reaction

$-r_A = k.C_A$

$-\ln(1 - X_A) = kt$

$-\ln(1-0.70) = k * 13$

$\qquad k = 0.0926$ min^{-1}

For Mixed flow reactor(CSTR) : | | 4 |

$$\tau = \frac{C_{A0}.X_A}{(-r_A)}$$	1	
$$\tau = \frac{C_{A0}.X_A}{-r_A} = \frac{C_{A0}.X_A}{kC_{A0}(1-X_A)}$$	1	
$\tau = \frac{0.70}{0.0926(1-0.7)} = 25.2$ min.	1	
	1	
Space velocity(s) = $v_0/V = 1/\tau = 1/25.2$ Space velocity = 0.39 min^{-1}	1	