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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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| 1a | ii | Enthalpy: <br> Enthalpy is the total heat content of a body. <br> Mathematical equation: <br> $\mathrm{H}=\mathrm{U}+\mathrm{PV}$ <br> Gibb's free energy: It is the energy actually available to do useful work. It <br> predicts the feasibility and equilibrium conditions for chemical reactions at <br> constant temperature and pressure. <br> Mathematical equation: <br> G= H-TS | 1 |
| :--- | :--- | :--- | :--- |

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\begin{tabular}{|c|c|c|c|}
\hline \multicolumn{2}{|r|}{1b} \& Attempt any ONE of the following \& 06 \\
\hline 1b \& i \& \begin{tabular}{l}
Method of analysis of kinetic data \\
1. Integral method of analysis \\
2. Differential method of analysis \\
3. Analysis of total pressure data \\
Differential method of analysis of data \\
1)Assume a mechanism and from it obtain a rate equation of the form
\[
-r_{A}=\frac{-d C_{A}}{d t}=k f(c)
\] \\
2) From experiment obtain concentration-time data and plot them. \\
3) Draw a smooth curve through this data. \\
4) Determine the slope of this curve at suitably selected concentration values. These slopes \(\left(\frac{-d C_{A}}{d t}\right)\) are the rates of reaction at these composition. \\
5) Evaluate \(f(c)\) for each composition. \\
6) Plot \(\frac{-d C_{A}}{d t} v s f(c)\) for each composition.If we get a straight line through origin; the rate equation is consistent with the data. If not, then another rate equation should be tested.
\end{tabular} \& 2

3
3
1 <br>
\hline
\end{tabular}

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\begin{tabular}{|c|c|c|c|}
\hline 1b \& ii \& \begin{tabular}{l}
Activation energy: \\
It is the minimum energy that the reactant molecules must acquire before reaction takes place to give the product.
\[
\begin{array}{|ll}
\mathrm{T}_{1}=10^{0} \mathrm{C}=283 \mathrm{~K} \& \mathrm{~T}_{2}=30^{0} \mathrm{C}=303 \mathrm{~K} \\
\mathrm{~K}_{1}=1.6 * 10^{-3} \mathrm{~S}^{-1} \& \mathrm{~K}_{2}=1.625 * 10^{-2} \mathrm{~S}^{-1}
\end{array}
\] \\
From Arrhenius law
\[
\begin{aligned}
\& \ln \frac{k_{2}}{k_{1}}=\frac{-E}{R}\left(\frac{1}{T_{2}}-\frac{1}{T_{1}}\right)= \\
\& \ln \frac{0.01625}{0.0016}=(-E / 8.314) \times\left(\frac{1}{303}-\frac{1}{283}\right)
\end{aligned}
\] \\
Activation energy \(\mathrm{E}=\mathbf{8 2 6 3 0 . 2 8} \mathbf{J} / \mathbf{m o l e}=\mathbf{1 9 6 7 3 . 8 7} \mathbf{~ c a l} / \mathbf{~ m o l}\) \\
\(\ln \mathrm{k}_{1}=\ln \mathrm{k}_{0}-\frac{E}{R T_{1}}\) \\
\(\ln 0.0016=\ln \mathrm{k}_{0}-(82630.28 /(8.314 * 283))\) \\
ln \(\mathrm{k}_{0}=2868129911\) \\
Frequency factor \(\mathrm{k}_{0}=\mathbf{2 . 8 5 8} * \mathbf{1 0}^{\mathbf{1 2}}\)
\end{tabular} \& 2

2
2

2 <br>
\hline 2 \& \& Attempt any TWO of the following \& 16 <br>
\hline 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 $\mathrm{kT} / \mathrm{h}$ where k is Boltzmann constant and h is Planck constant. Consider the reversible reaction $\mathrm{A}+\mathrm{B} \leftrightarrow \mathrm{AB}, \mathrm{k}_{1}$ is the rate constant for forward reaction and $k_{2}$ is the rate constant for backward reaction \& 2 <br>
\hline
\end{tabular}

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| 2 | b | Derivation of performance equation of mixed flow reactor in which first order reaction is taking place: <br> In MFR, the composition of the reactants is uniform throughout the reactor. <br> Taking material balance of reactant A over the reactor as a whole, <br> Rate of input of A to the reactor $=$ Rate of output of A from the reactor + <br> Rate of disappearance of A due to chemical reaction + Rate of accumulation of A within the reactor. <br> For mixed flow reactor at steady state the last term is zero. Therefore the material balance equation becomes <br> Rate of input of A to the reactor $=$ Rate of output of A from the reactor + <br> Rate of disappearance of A due to chemical reaction <br> Let, $\quad F_{A 0}=$ Molar feed rate to the reactor <br> $\mathrm{V}=$ Volume of reactor <br> $\mathrm{C}_{\mathrm{A} 0}=$ Molar concentration of A in stream entering the reactor ( moles/volume) <br> $\mathrm{v}_{0}=$ Volumetric flow rate(volume/time) <br> $X_{A}=$ Fractional conversion of $A$ $\mathrm{F}_{\mathrm{A} 0}=\mathrm{C}_{\mathrm{A} 0 .} \mathrm{v}_{0}$ <br> Input of $A$ to the reactor in moles / time $=F_{A 0}$. <br> Disappearance of A due chemical reaction in moles / time $=\left(-\mathrm{r}_{\mathrm{A}}\right) \cdot \mathrm{V}$ <br> Output of A from the reactor in moles / time $=\mathrm{F}_{\mathrm{A}}$ <br> Substituting in (i) $\begin{equation*} \mathrm{F}_{\mathrm{A} 0}=\mathrm{F}_{\mathrm{A}}+\left(-\mathrm{r}_{\mathrm{A}}\right) \cdot \mathrm{V} \tag{ii} \end{equation*}$ <br> But $\mathrm{F}_{\mathrm{A}}=\mathrm{F}_{\mathrm{A} 0}\left(1-\mathrm{X}_{\mathrm{A}}\right)=\mathrm{F}_{\mathrm{A} 0}-\mathrm{F}_{\mathrm{A} 0} . \mathrm{X}_{\mathrm{A}}$ <br> Equation (ii) becomes $\mathrm{F}_{\mathrm{A} 0}=\mathrm{F}_{\mathrm{A} 0}-\mathrm{F}_{\mathrm{A} 0} . \mathrm{X}_{\mathrm{A}}+\left(-\mathrm{r}_{\mathrm{A}}\right) \cdot \mathrm{V}$ | 1 |
| :---: | :---: | :---: | :---: |

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\begin{tabular}{|c|c|c|c|}
\hline \& \&  \& \\
\hline 2 \& c \& \begin{tabular}{l}
Auto catalysis: \\
A reaction in which one of the products of the reaction acts as a catalyst is called as an autocatalytic reactions. \\
Example: Oxidation of a solution of oxalic acid by an acidified solution of \(\mathrm{KMnO}_{4}\). \\
Promoters: \\
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. \\
Inhibitors: \\
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. \\
Accelerators: \\
A material added to the reactant stream to improve the performance of a catalyst is known as accelerators.
\end{tabular} \& 2

2
2
2
2
2 <br>
\hline \multicolumn{2}{|l|}{3} \& Attempt any FOUR of the following \& 16 <br>
\hline 3 \& a \& Relation between equilibrium conversion and thermodynamic equilibrium constant(Derivation) \& <br>
\hline
\end{tabular}

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| 3 | c | $\begin{aligned} & \mathrm{C}_{\mathrm{p}}(\text { ice })=9.0145 \mathrm{cal} / \mathrm{g} \text { mole } \mathrm{K} \\ & \mathrm{C}_{\mathrm{p}}(\text { water })=18 \mathrm{cal} / \mathrm{g} \text { mole } \mathrm{K} \end{aligned}$ <br> Molar enthalpy of fusion $=1437.1 \mathrm{cal} / \mathrm{g}$ mole <br> 1. Entropy change when 2 moles of ice is heated from $-10^{\circ} \mathrm{C}$ to $0^{\circ} \mathrm{C}$ $\begin{aligned} \Delta \mathrm{S}_{1} & =\mathrm{nC}_{\mathrm{p}(\text { ice })} \int_{T_{1}}^{T_{2}} d \ln T=\mathrm{nC}_{\mathrm{p}(\text { ice })} \ln \frac{T_{2}}{T_{1}}=2 * 9.0145^{*} \ln (273 / 263) \\ & =0.6728 \mathrm{cal} / \mathrm{K} \end{aligned}$ <br> 2. Entropy change when 2 molse of ice at $0^{\circ} \mathrm{C}$ is converted to water at $0^{\circ} \mathrm{C}$ $\Delta \mathrm{S}_{2}=\mathrm{n} \Delta \mathrm{H} \text { fusion } / \mathrm{T}_{\text {fusion }}=2^{*} 1437.1 / 273=10.5282 \mathrm{cal} / \mathrm{k}$ <br> 3. Entropy change when 2 moles of water is heated from $0^{\circ} \mathrm{C}$ to $10^{\circ} \mathrm{C}$ $\Delta \mathrm{S}_{3}=\mathrm{nC}_{\mathrm{p}(\text { water })} \int_{T_{1}}^{T_{2}} d \ln T=2 * 18 * \ln (283 / 273)=1.295 \mathrm{cal} / \mathrm{k}$ <br> Total entropy change $\Delta \mathrm{S}=\Delta \mathrm{S}_{1}+\Delta \mathrm{S}_{2}+\Delta \mathrm{S}_{3}=\mathbf{1 2 . 4 9 6} \mathbf{c a l} / \mathrm{K}$ | 1 <br> 1 <br> 1 |
| :---: | :---: | :---: | :---: |
| 3 | d | Factors affecting the rate of a chemical reaction (any four) : <br> 1. In homogeneous system temperature, pressure and composition are the variables. <br> 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. <br> 1. rate of heat transfer <br> 2. Catalyst <br> 3. Nature of reactants <br> 4. Surface area available. <br> 5. Intensity of light if reaction is light sensitive. | 1 mark each |

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|  |  | $\begin{aligned} & \quad \mathrm{t}=10 \mathrm{~min} \\ & \quad 6.5=\frac{1}{10}\left[\frac{1}{C_{A}}-\frac{1}{0.03}\right] \\ & \mathrm{C}_{\mathrm{A}}=0.01017 \mathrm{~mol} / \mathrm{l} \\ & \text { Proportion of ester hydrolyzed }=\frac{C_{A O}-C_{A}}{C_{A O}}=\frac{0.03-0.01017}{0.03}=0.661=\mathbf{6 6 . 1 \%} \end{aligned}$ | 2 |
| :---: | :---: | :---: | :---: |
| 4a | ii | Desired properties of catalyst (any four) <br> 1. Porosity <br> 2. Large surface area <br> 3. High selectivity <br> 4. High activity <br> 5. Low kindling point <br> 6. High accessibility <br> 7. Long life and regenerability <br> 8. Adequate thermal / mechanical strength in reaction conditions <br> 9. Non toxic and cheap <br> Definition (any two) <br> 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 the rate constant of a catalysed and uncatalysed reaction. <br> 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. <br> Porosity is defined as the ratio of volume of voids to the total volume of catalyst. <br> 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. | $1 / 2$ mark <br> each <br> 1 mark each |

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| 4a | iii | Graphical representation of integrated rate equation for second order <br> reaction 2A $\rightarrow$ Product: <br> In terms of concentration: |  |
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|  |  | $\begin{array}{ll} \mathrm{E}_{1}=17982 \mathrm{cal} / \mathrm{mol} & \mathrm{E}_{2}=11980 \mathrm{cal} / \mathrm{mol} \\ \mathrm{~T}=25^{\circ} \mathrm{C}=298 \mathrm{~K} & \end{array}$ <br> For Un catalyzed reaction, $\mathrm{k}_{1}=\mathrm{k}_{0} \mathrm{e}_{-} \mathrm{E}_{1} / \mathrm{RT}$ and <br> For catalyzed reaction $\mathrm{k}_{2}=\mathrm{k}_{0} \mathrm{e}-{ }^{\mathrm{E}}{ }_{2} / \mathrm{RT}$ $\begin{align*} & \ln \mathrm{k}_{1}=\ln \text { ko }-\frac{E_{1}}{R T} \ldots \ldots  \tag{1}\\ & \ln \mathrm{k}_{2}=\ln \mathrm{ko}-\frac{E_{2}}{R T} \ldots \end{align*}$ <br> (2) - (1) gives $\ln \frac{k_{2}}{k_{1}}=\frac{E_{1}-E_{2}}{R T}=\frac{17982-11980}{1.987 * 298}=10.136$ $\begin{aligned} & \frac{k_{2}}{k_{1}}=25,244 \\ & \mathrm{k}_{2}=25,244 \mathrm{k}_{1} \end{aligned}$ <br> ie Catalyzed reaction is $\mathbf{2 5 , 2 4 4}$ times faster than un catalyzed reaction | 2 2 2 |
| :---: | :---: | :---: | :---: |
| 4b | ii | Relation between $K_{p}$, $K_{y}$ and $K_{c}$ <br> Consider the reaction $\mathrm{aA}+\mathrm{bB}+\ldots . \rightarrow \mathrm{rR}+\mathrm{sS} \ldots \ldots$. $\mathrm{K}_{\mathrm{c}}=\left(\mathrm{C}_{\mathrm{R}}{ }^{\mathrm{r}} \cdot \mathrm{C}_{\mathrm{S}}^{\mathrm{s}}\right) /\left(\mathrm{C}_{\mathrm{A}}{ }^{\mathrm{a}} \cdot \mathrm{C}_{\mathrm{B}}{ }^{\mathrm{b}}\right)$ <br> For ideal gas $\mathrm{C}_{\mathrm{i}}=\mathrm{p}_{\mathrm{i}} / \mathrm{RT}$ <br> Therefore $\mathrm{K}_{\mathrm{c}}=\left\{\left(\mathrm{p}_{\mathrm{R}} / \mathrm{RT}\right)^{\mathrm{r}} .\left(\mathrm{p}_{\mathrm{S}} / \mathrm{RT}\right)^{\mathrm{s}}\right\} /\left\{\left(\mathrm{p}_{\mathrm{A}} / \mathrm{RT}\right)^{\mathrm{a}} \cdot\left(\mathrm{p}_{\mathrm{B}} / \mathrm{RT}\right)^{\mathrm{b}}\right\}$ $=\left(p_{R}{ }^{\mathrm{r}} \cdot \mathrm{p}_{\mathrm{S}}{ }^{\mathrm{s}}\right) /\left(\mathrm{p}_{\mathrm{A}}{ }^{\mathrm{a}} \cdot \mathrm{p}_{\mathrm{B}}{ }^{\mathrm{b}}\right) \cdot(1 / \mathrm{RT})^{(\mathrm{r}+\mathrm{s}+\ldots-(\mathrm{a}+\mathrm{b}=\ldots))}$ <br> R is the ideal gas constant <br> T the absolute temperature in K <br> P is the pressure in atm $\mathrm{ieK}_{\mathrm{c}}=\mathrm{K}_{\mathrm{p}} \cdot(1 / \mathrm{RT})^{\Delta \mathrm{n}} \text { where } \mathrm{K}_{\mathrm{p}}=\left(\mathrm{p}_{\mathrm{R}}{ }^{\mathrm{r}} \cdot \mathrm{p}_{\mathrm{s}}{ }^{\mathrm{s}}\right) /\left(\mathrm{p}_{\mathrm{A}}{ }^{\mathrm{a}} \cdot \mathrm{p}_{\mathrm{B}}{ }^{\mathrm{b}}\right)$ <br> $\Delta \mathrm{n}=(\mathrm{r}+\mathrm{s}+\ldots-(\mathrm{a}+\mathrm{b}+\ldots)$.$) is the difference in the number of moles of$ product and reactant $\begin{aligned} & \text { Or } \mathbf{K}_{\mathbf{p}}=\mathbf{K}_{\mathbf{c}} \times(\mathbf{R T})^{\Delta}{ }^{\mathbf{n}} \\ & \mathrm{K}_{\mathrm{p}}=\left(\mathrm{p}_{\mathrm{R}}{ }^{\mathrm{r}} \cdot \mathrm{p}_{\mathrm{s}}{ }^{\mathrm{s}}\right) /\left(\mathrm{p}_{\mathrm{A}}{ }^{\mathrm{a}} \cdot \mathrm{p}_{\mathrm{B}}{ }^{\mathrm{b}}\right) \end{aligned}$ | 3 |

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|  |  | But $\mathrm{p}_{\mathrm{A}}=\mathrm{P} . \mathrm{y}_{\mathrm{A}}$ Where $\mathrm{p}_{\mathrm{A}}-$ partial pressure of $\mathrm{A}, \mathrm{P}$ - total pressure $y_{A}$ - mole fraction of $A$. $\begin{aligned} \mathrm{K}_{\mathrm{p}} & =\left(\mathrm{p}_{\mathrm{R}}{ }^{\mathrm{r}} \cdot \mathrm{p}_{\mathrm{s}}{ }^{\mathrm{s}}\right) /\left(\mathrm{p}_{\mathrm{A}}{ }^{\mathrm{a}} \cdot \mathrm{p}_{\mathrm{B}}{ }^{\mathrm{b}}\right) \\ & =\left\{\left(\mathrm{Py}_{\mathrm{R}}\right)^{\mathrm{r}} \cdot\left(\mathrm{Py}_{\mathrm{S}}\right)^{\mathrm{s}}\right\} /\left\{\left(\mathrm{Py}_{A}\right)^{\mathrm{a}} \cdot\left(\mathrm{Py}_{\mathrm{B}}\right)^{\mathrm{b}}\right\} \\ & =\left(\mathrm{y}_{\mathrm{R}}{ }^{\mathrm{r}} \cdot \mathrm{ys}^{\mathrm{s}}\right) /\left(\mathrm{y}_{A}{ }^{\mathrm{a}} \cdot \mathrm{y}_{\mathrm{B}}{ }^{\mathrm{b}}\right) \cdot \mathrm{P}^{(\mathrm{r}+\mathrm{s}+\ldots)-(\mathrm{a}+\mathrm{b}+\ldots))} \end{aligned}$ <br> $K_{p}=K_{y} \cdot P^{\Delta n} \quad$ where $K_{y}=\left(y_{R}{ }^{\mathrm{r}} \cdot \mathrm{ys}^{5}\right) /\left(\mathrm{y}_{\mathrm{A}}{ }^{\mathrm{a}} \cdot \mathrm{y}_{\mathrm{B}}{ }^{\mathrm{b}}\right)$ and <br> $\Delta \mathrm{n}=(\mathrm{r}+\mathrm{s}+\ldots)-(\mathrm{a}+\mathrm{b}+\ldots))$ is the difference in the number of moles of product and reactant $K_{c}=K_{p}(1 / R T)^{\Delta n}=K_{y}(P / R T)^{\Delta n}$ | 3 |
| :---: | :---: | :---: | :---: |
| 5 |  | Attempt any TWO of the following | 16 |
| 5 | a | Integrated rate expression for constant volume irreversible unimolecular first order reaction (derivation): <br> Consider the reaction $\mathrm{A} \rightarrow \mathrm{B}$ <br> In terms of concentration <br> The rate equation is $-\mathrm{r}_{\mathrm{A}}=-\mathrm{dC}_{\mathrm{A}} / \mathrm{dt}=\mathrm{kC}_{\mathrm{A}} \ldots$. (1) <br> Rearranging - $\frac{d C_{A}}{C_{A}}=\mathrm{kdt}$ <br> Integrating between appropriate limits $-\int_{C_{A O} O}^{C_{A}} \frac{d C_{A}}{C_{A}} \quad=\mathrm{k} \int_{0}^{t} d t$ <br> $-\left(\ln \mathrm{C}_{\mathrm{A}} / \mathrm{C}_{\mathrm{A} 0}\right)=k t$ | 2 |

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|  |  | $\begin{gathered} \frac{V}{F_{A 0}}=9(\mathrm{l} . \mathrm{sec} / \mathrm{mol}) \\ \mathrm{V}=9 * F_{A 0}=9 * 10=90 \text { lit. } \\ \text { Volume of CSTR }=\mathbf{9 0} \text { lit. } \end{gathered}$ <br> For a plug flow reactor $\frac{V}{F_{A 0}}$ is the area under the curve from $X_{A}=0$ to $X_{A}=$ 0.6 <br> Area under the curve $=21.5 \mathrm{~cm}^{2}$ $\begin{gathered} \frac{V}{F_{A 0}}=\text { Area } X(\text { Scale on } X-\text { axis }) X(\text { Scale on } Y-\text { axis }) \\ \frac{V}{F_{A 0}}=21.5 \mathrm{~cm}^{2} \times \frac{5(l . s e c / m o l}{2 \mathrm{~cm}} \times \frac{0.1}{1 \mathrm{~cm}} \\ \frac{V}{F_{A 0}}=5.375 \\ \mathrm{~V}=5.375 \mathrm{X} F_{A 0}=5.375 \mathrm{X} 10=53.75 \mathrm{lit} \\ \text { Volume of } \mathbf{P F R}=\mathbf{5 3 . 7 5} \text { lit. } \end{gathered}$ <br> Volume of PFR( 53.75 lit.) is less than the volume of CSTR (90 lit.) for the same conversion. ( $X_{A}=0.6$ ) | 2 |
| :---: | :---: | :---: | :---: |
| 5 | c | Design equation of batch reactor <br> In batch reactor, the composition is uniform throughout reaction zone at any instant of time. <br> Taking material balance of a limiting reactant A , over the reactor as a whole <br> Rate of reactant A in $=$ Rate of reactant A out + Rate of loss of reactant A <br> due to chemical reaction + Rate of accumulation of reactant A within the reactor. <br> In a batch reactor, no fluid enters or leaves the reaction mixture during the | 2 |

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|  |  |  <br> For constant volume system |  |
| :---: | :---: | :---: | :---: |
| 6 |  | Attempt any FOUR of the following | 16 |
| 6 | a | Method of feeding when PFR's are connected in parallel <br> Consider PFRs are connected as shown in the figure. <br> 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 or $\tau$ must be the same for each parallel line. Any other method of feeding is inefficient. <br> Ie $\left(\frac{V}{F}\right)$ for branch $\mathrm{A}=\left(\frac{V}{F}\right)$ for branch B $\left(\frac{F_{01}}{F_{02}}\right)=\left(\frac{V_{1}}{V_{2}}\right)$ <br> For example: <br> If $\mathrm{V}_{1}=80$ lit \& $\mathrm{V}_{2}=40$ lit | 2 |

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|  |  | $\begin{aligned} & \left(\frac{F_{01}}{F_{02}}\right)=\left(\frac{V_{1}}{V_{2}}\right)=\frac{80}{40}=2 \\ & \mathrm{~F}_{\mathrm{o} 1}=2 \mathrm{~F}_{\mathrm{o} 2} \end{aligned}$ <br> Total feed $\mathrm{F}=\mathrm{F}_{\mathrm{o} 1}+\mathrm{F}_{\mathrm{o} 2}=2 \mathrm{~F}_{\mathrm{o} 2}+\mathrm{F}_{\mathrm{o} 2}=3 \mathrm{~F}_{\mathrm{o} 2}$ <br> Fraction of feed fed to branch $\mathrm{A}=\mathrm{F}_{\mathrm{o} 1} / \mathrm{F}=2 \mathrm{~F}_{\mathrm{o} 2} / 3 \mathrm{~F}_{\mathrm{o} 2}=2 / 3$ <br> Fraction of feed fed to branch $B=F_{02} / F=F_{02} / 3 F_{02}=1 / 3$ | 2 |
| :---: | :---: | :---: | :---: |
| 6 | b | Entropy change of an ideal gas: <br> From first law of thermodynamics, $\mathrm{dU}=\mathrm{dQ}-\mathrm{dW}$ $\begin{equation*} \mathrm{dQ}=\mathrm{dU}+\mathrm{dW} \tag{i} \end{equation*}$ <br> But dQ = TdS $\begin{equation*} \mathrm{dW}=\mathrm{PdV} \tag{ii} \end{equation*}$ <br> For ideal gas $\mathrm{dU}=\mathrm{n}_{\mathrm{v}} \mathrm{dT}$ <br> Substituting ii,iii and iv in i $\begin{aligned} & \mathrm{TdS}=\mathrm{n} \mathrm{C}_{\mathrm{v}} \mathrm{dT}+\mathrm{PdV} \\ & \mathrm{dS}=\frac{\mathrm{nCvdT}}{T}+\frac{P d V}{T} \end{aligned}$ <br> For ideal gas $\mathrm{P}=\frac{n R T}{V}$ <br> Substituting dS $=\frac{\mathrm{nCvdT}}{T}+\frac{n R d V}{V}$ <br> Integrating between limits $\begin{aligned} & \int_{S_{1}}^{S_{2}} \mathrm{dS}=\mathrm{nC}_{\mathrm{v}} \int_{T_{1}}^{T_{2}} \frac{d T}{T}+\mathrm{nR} \int_{V_{1}}^{V_{2}} \frac{d V}{V} \\ & \Delta \mathrm{~S}=\mathrm{nC}_{\mathrm{v}} \ln \frac{T_{2}}{T_{1}}+\mathrm{nR} \ln \frac{V_{2}}{V_{1}} \ldots \ldots(\mathrm{v}) \end{aligned}$ <br> For ideal gas $\mathrm{PV}=\mathrm{RT}$ $\begin{equation*} \frac{P_{2} V_{2}}{P_{1} V_{1}}=\frac{T_{2}}{T_{1}} \tag{vi} \end{equation*}$ <br> Therefore $\frac{V_{2}}{V_{1}}=\frac{T_{2} P_{1}}{T_{1} P_{2}}$. | 2 |

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\begin{tabular}{|c|c|c|c|}
\hline \& \& \begin{tabular}{l}
Also \(\mathrm{Cp}-\mathrm{Cv}=\mathrm{R}\) \\
Substituting vi and vii in \(v\)
\[
\begin{aligned}
\& \Delta \mathrm{S}=\mathrm{n}\left(\mathrm{C}_{\mathrm{p}}-\mathrm{R}\right) \ln \frac{T_{2}}{T_{1}}+\mathrm{nR} \ln \frac{T_{2} P_{1}}{T_{1} P_{2}} \\
\& \Delta \mathrm{~S}=\mathrm{nC}_{\mathrm{p}} \ln \frac{T_{2}}{T_{1}}+\mathrm{nR} \ln \frac{P_{1}}{P_{2}}
\end{aligned}
\]
\end{tabular} \& 2 \\
\hline 6 \& c \& \begin{tabular}{l}
Chain reaction: \\
In Chain reaction, the intermediate is formed in the first reaction called chain initiation step. It then combines with the reactant to form product and more intermediates in the chain propagation step. Occasionally these intermediates are destroyed in chain termination step. \\
Non-chain reaction: \\
In non chain reaction, the intermediate is formed in the first reaction and then disappears as it reacts further to give products. \\
Reactants \(\rightarrow \quad\) (Intermediates)* \\
(Intermediates)* \(\rightarrow \quad\) Products
\end{tabular} \& 2

2 <br>

\hline 6 \& d \& | Integrated form of rate expression for zero order reaction Rate equation is $-\mathrm{r}_{\mathrm{A}}=-\frac{d C_{A}}{d t}=\mathrm{C}_{\mathrm{A} 0} \frac{d_{x A}}{d t}=\mathrm{k}$ |
| :--- |
| In terms of concentration $-\frac{d C_{A}}{d t}=\mathrm{k}$ |
| Integrating between appropriate limits $\int_{C A_{0}}^{C A}-\mathrm{dCA}=\mathrm{k} \int_{0}^{t} d t$ | \& 2 <br>

\hline
\end{tabular}

## WINTER-19 EXAMINATION

## Model Answer

Subject title: Chemical Reaction Engineering $\quad$ Subject code $\quad 17562$

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|  |  | $\mathrm{C}_{\mathrm{A} 0}-\mathrm{C}_{\mathrm{A}}=\mathrm{kt} \text { for } \mathrm{t} \leqslant \frac{C_{A 0}}{k}$ <br> In terms of fractional conversion $\mathrm{C}_{\mathrm{A} 0} \frac{d_{x A}}{d t}=\mathrm{k}$ <br> Integrating between appropriate limits $\begin{aligned} & C_{A 0} \int_{0}^{x A} \mathrm{~d}_{\mathrm{xA}}=\mathrm{k} \int_{0}^{t} d t \\ & \quad \mathrm{C}_{\mathrm{A} 0} \mathrm{X}_{\mathrm{A}}=\mathrm{kt} \text { for } \mathrm{t} k \frac{C_{A 0}}{k} \end{aligned}$  | 2 |
| :---: | :---: | :---: | :---: |
| 6 | e | Batch reactor <br> Advantages (2 each): <br> 1. Simple in construction \& operation | 1 mark each |


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| :--- | ---: | ---: |


|  | 2. Low equipment cost <br> 3. Gives highest conversion by leaving the reactants for longer periods in <br> reactor. <br> 4. Requires small instrumentation \& less supporting equipment. <br> Disadvantages (2 each): <br> 1. High labor costs per unit volume of production. <br> 2. Requires considerable time to empty, clean out \& refill. <br> 3. Poorer quality control of product. <br> 4. Large scale production is difficult. |  |
| :--- | :--- | :--- |

