



8 MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION

(Autonomous)

(ISO/IEC - 27001 - 2005 Certified)

SUMMER-19 EXAMINATION

Model Answer

Subject Title: Stoichiometry

Subject code : 17315

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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	marks
1A	<b>Any 4</b>	<b>8</b>
1A(i)	<b>Raoult's law:</b> It states that at a given temperature, the equilibrium partial pressure of a component of a solution in the vapour is equal to the product of the mole fraction of the component in the liquid phase and the vapour pressure of the pure component. <b>Henry's law:</b> It states that the partial pressure of the solute gas in gas phase is directly proportional to the mole fraction of a solute gas dissolved in a liquid equilibrium above the liquid surface.	1 1
1A(ii)	<b>Limiting reactant in a chemical reaction:</b> It is the reactant which decides the extent of a reaction. Or It is the reactant which is added in limited quantity. Or It is the reactant which disappear first if a reaction goes to completion <b>Excess reactant:</b> It is the reactant which is in excess of the theoretical or stoichiometric requirement.	1 1
1A (iii)	<b>Standard heat of formation :</b> It is the amount of heat liberated or absorbed when one mol of a compound is formed from its elements at standard conditions. <b>Standard heat of combustion:</b> It is the amount of heat liberated when one mol of a compound is combusted or burned in oxygen at standard conditions. (25 <sup>0</sup> C and 1atm pressure)	1 1
1A (iv)	<b>Recycling:</b> It is returning back a portion of stream leaving a process unit to the entrance of the process unit for further processing.	1

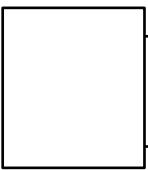


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	<p><b>Reasons for performing recycling:</b> (any one)</p> <ol style="list-style-type: none"> <li>1. Maximum utilization of the valuable reactant</li> <li>2. Improvement of the performance of the equipment/ operation</li> <li>3. Utilization of the heat being lost in the exit stream.</li> <li>4. Better operating conditions of the system</li> <li>5. Improvement in the selectivity of a product</li> <li>6. Enrichment of a product</li> </ol>	1
1A(v)	<p><b>Partial pressure:</b> Partial pressure of a component gas is the pressure that would be exerted by that component gas if it alone was present in the same volume and at the same temperature as the gas mixture.</p> <p><b>Pure component volume:</b> Pure component volume of a component gas is the volume that would be occupied by that component gas if it alone was present in the same pressure and at the same temperature as the gas mixture.</p>	1 1
1A (vi)	<p><b>CO + H<sub>2</sub> ---→CH<sub>3</sub>OH</b></p> <p><i>Note: Question is incomplete. Mark should be given for attempting the question</i></p>	2
<b>1-B</b>	<b>Any 2</b>	<b>12</b>
1-B (i)	<p>Basis : 500 kg phenol and 700 kg H<sub>2</sub>O</p> <p>1200 kg feed →  → Phenol rich layer X kg Water rich layer Y kg.</p> <p>Overall balance is 100 = X + Y ..... (1) Material balance for phenol is</p>	1 1 1



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	500 = 0.7X + 0.09Y..... (2) Solving 1 and 2 Y = 557.37 kg, X = 642.62 kg Weight of Phenol rich layer = <b>642.62 kg</b> Weight of Water rich layer = <b>557.37 kg</b>	1    1  1
1-B (ii)	Basis: 5 kg CaC <sub>2</sub> CaC <sub>2</sub> + H <sub>2</sub> O --→ C <sub>2</sub> H <sub>2</sub> + Ca(OH) <sub>2</sub> Kmoles of CaC <sub>2</sub> = 5/64 = 0.07812 C <sub>2</sub> H <sub>2</sub> produced = 0.07812 kmoles PV = nRT Or V = nRT/P = 0.07812 * 8.314 * 313 / 100 = <b>2.03 m<sup>3</sup></b>	1  1  1  1  1
1- B(iii)	<b>SO<sub>2</sub> + ½ O<sub>2</sub> --→ SO<sub>3</sub></b> Basis: 1 kmol SO <sub>2</sub> Theoretical oxygen requirement = 0.5 kmol % excess air = 80% O <sub>2</sub> fed = 0.5 + 0.8*0.5 = 0.9 kmole Fed air = 0.9 * 100 / 21 = 4.2857 kmoles N <sub>2</sub> from fed air = 4.2857 * 0.79 = 3.39 kmoles Conversion = 70% Reacted SO <sub>2</sub> = 0.7 kmole Reacted O <sub>2</sub> = 0.5*0.7 = 0.35 kmole Unreacted O <sub>2</sub> = 0.9-0.35 = 0.55 kmole Unreacted SO <sub>2</sub> = 1-0.7 = 0.3 kmoles Formed SO <sub>3</sub> = 0.7 kmoles N <sub>2</sub> = 3.39 kmoles	1    1   1  1  1



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	component	kmoles	Mol%	
	O <sub>2</sub>	0.55	11.13	1
	SO <sub>2</sub>	0.3	6.07	
	SO <sub>3</sub>	0.7	14.17	
	N <sub>2</sub>	3.39	68.62	
2	<b>Any 4</b>			<b>16</b>
2-i	<p><b>Basis:</b> 50 kmoles /hr butane</p> $\text{C}_4\text{H}_{10} + 6.5 \text{O}_2 \rightarrow 4\text{CO}_2 + 5 \text{H}_2\text{O}$ <p>100 kmol air fed = 21 kmol O<sub>2</sub> fed            2100 kmol air fed = ?            O<sub>2</sub> fed = 2100*21/100= 441kmoles            1 kmol C<sub>4</sub>H<sub>10</sub> fed = 6.5 kmol O<sub>2</sub> theoretically required            50 kmol C<sub>4</sub>H<sub>10</sub> fed = ?            O<sub>2</sub> theoretically required = 325 kmol            % excess= (O<sub>2</sub> fed-O<sub>2</sub> theoretical)*100/ O<sub>2</sub> theoretical                      = (441-325)*100/325                      = <b>35.69%</b></p>			1  1 1 1
2-ii	<p><b>Hess's law of constant heat summation :</b> It states that the enthalpy change i.e. heat evolved or absorbed in a particular reaction is the same whether the reaction takes place in one or several steps.</p> <p>For Example : Carbon can be converted into CO<sub>2</sub> by two ways</p> <p>Path 1 : C (s) + O<sub>2</sub> (g) → CO<sub>2</sub>(g)      Δ H</p> <p>Path 2 : (i) C (s) + ½ O<sub>2</sub> (g) → CO (g)      Δ H1                      (ii) 2CO (g) + ½ O<sub>2</sub> (g) → CO<sub>2</sub>(g)      Δ H2                      -----</p>			2   2



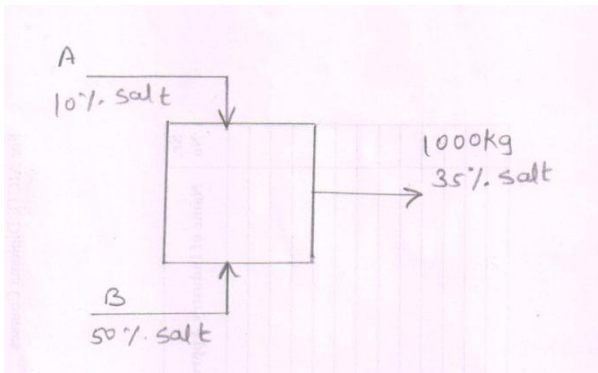
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	(i) + (ii) $C(s) + O_2(g) \rightarrow CO_2(g)$ Thus $\Delta H = \Delta H_1 + \Delta H_2$	
2-iii	<p>BASIS: 1000 kg of final solution.</p>  <p>Let kg of A=x Let kg of B=y Therefore overall balance <math>X+y=1000</math> .....(1) Salt balance <math>0.1x+0.5y=1000*0.35</math> <math>0.1x+0.5y=350</math> .....(2) Multiplying equation (1) by 0.1 <math>0.1x+0.1y=100</math> .....(3) From equation (2) and (3) <math>4y=250</math> Therefore <math>y=250/4</math> <math>=62.5\text{kg}</math> <math>X=375\text{kg}</math> <b>Wt of 10% solution=375 kg</b></p>	<p>1</p> <p>1</p> <p>1</p>



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	<p><b>Wt of 50% solution=625kg</b></p>	1
2-iv	<p>Basis: 1000 kg wet ONA</p> <div style="text-align: center; margin: 20px 0;"> <pre>         graph LR           Feed[1000 Kg feed 90% solid] --&gt; Dryer[dryer]           Dryer --&gt; Water[Water Xkg]           Dryer --&gt; Product[Product Y kg 0.5% moisture]           style Dryer fill:#fff,stroke:#000,stroke-width:2px         </pre> </div> <p>Overall balance is  <math>1000 = X + Y</math></p> <p>Balance for solid  <math>0.90 * 1000 = 0.995 * Y</math>  <math>Y = 904.52 \text{ kg}</math>  <math>X = 95.48\textbf{kg}</math>          Water removed = <math>95.48\textbf{kg}</math>          Product obtained = <math>904.52 \text{ kg}</math></p> <p><b>% of original water removed</b> = <math>(\text{Water removed/original water} * 100)</math>  <math>= (95.48/100) * 100 = 95.48\%</math></p>	1            1           1
2-v	<p><b>Basis:</b> Average molecular weight of gas mixture=22.4</p> <p>Let <math>X_A</math> &amp; <math>X_B</math> be the mole fractions of <math>\text{CH}_4</math> &amp; <math>\text{C}_2\text{H}_6</math> respectively</p> <p><math>M_{av} = M_A X_A + M_B X_B</math>  <math>22.4 = 16X_A + 30X_B \dots\dots\dots(1)</math></p> <p><math>1 = X_A + X_B \dots\dots\dots(2)</math></p> <p>Solving (1) &amp; (2) we get</p>	1            1           1



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	$X_A = 0.543$ and $X_B = 0.457$ <b>Mole fraction of <math>CH_4 = 0.543</math> &amp; Mole fraction of <math>C_2H_4 = 0.457</math></b>	1												
2-vi	<p>Basis : 100 kmol product stream</p> <p>Reaction is <math>2A + B \rightarrow C</math></p> <p>Kmol of inerts in product stream = 19.23 kmol</p> <p>Kmol of A in product stream = 23.08 kmol (unreacted)</p> <p>Kmol of B in product stream = 11.54 kmol (unreacted)</p> <p>Kmol of C in product stream = 46.15 kmol (product)</p> <p>Kmol of A reacted (from reaction) <math>2 * 46.15 = 92.3</math></p> <p>Kmol of A fed = Kmole of A reacted + Kmole of A unreacted</p> <p style="padding-left: 40px;"><math>= 92.3 + 23.08 = 115.38</math> kmol</p> <p>Kmol of B reacted (from reaction) = 46.15</p> <p>Kmol of B fed = Kmole of B reacted + Kmole of B unreacted</p> <p style="padding-left: 40px;"><math>= 46.15 + 11.54 = 57.69</math> kmol</p> <p>Inerts = 19.23 kmol</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>Component</th> <th>Kmol</th> <th>Mole %</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>115.38</td> <td>60</td> </tr> <tr> <td>B</td> <td>57.69</td> <td>30</td> </tr> <tr> <td>Inerts</td> <td>19.23</td> <td>10</td> </tr> </tbody> </table>	Component	Kmol	Mole %	A	115.38	60	B	57.69	30	Inerts	19.23	10	<p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p>
Component	Kmol	Mole %												
A	115.38	60												
B	57.69	30												
Inerts	19.23	10												
<b>3</b>	<b>Any 2</b>	<b>16</b>												
3-i	<p><b>Solution :Basis:</b> 100kg of product gases leaving the oxidizer</p> <div style="text-align: center; background-color: #f0f0f0; padding: 10px; border: 1px solid #ccc;"> </div> <p><b>Reaction:</b> <math>4 HCl + O_2 \rightarrow 2 Cl_2 + 2 H_2O</math></p> <p>Product gases contain 13.2 kg HCl, 6.3 kg <math>O_2</math>, 42.9kg <math>N_2</math>, 30 kg <math>Cl_2</math> and</p>	1												





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<p>7.6 kg H<sub>2</sub>O.</p> <p>Quantity of HCl unreacted = HCl in product gases = 13.2 kg</p> <p>Cl<sub>2</sub> produced = Cl<sub>2</sub> in product gases = 30kg</p> <p>We have from the reaction, 4 kmolHCl = 2 kmol Cl<sub>2</sub> i.e., 146 kg HCl = 142 kg Cl<sub>2</sub> (on weight basis)</p> <p>∴ Quantity of HCl reacted to produce 30 kg Cl<sub>2</sub> <math>= \frac{146}{142} \times 30 = 30.85 \text{ kg}</math></p> <p><b>Material balance of HCl:</b> HCl charged = HCl reacted + HCl unreacted</p> <p>∴ HCl charged = 30.85 + 13.2 = 44.05 kg</p> <p>Moles of HCl Charged = <math>\frac{44.05}{36.5} = 1.2068 \text{ kmol}</math></p> <p>We have, 4 kmolHCl = 1 kmol O<sub>2</sub> .... Mole basis</p> <p>∴ 146 kg HCl = 32 kg O<sub>2</sub> .... Weight basis</p> <p>∴ Quantity of O<sub>2</sub> reacted with 30.85 kg HCl = <math>\frac{32}{146} \times 30.85 = 6.76 \text{ kg}</math></p> <p><b>Material balance of O<sub>2</sub>:</b> O<sub>2</sub> charged = O<sub>2</sub> reacted + O<sub>2</sub> unreacted</p> <p>= 6.76 + 6.3 = 13.06 kg</p> <p>N<sub>2</sub> charged = N<sub>2</sub> in product gaes = 42.9 kg</p> <p>∴ Air charged = (O<sub>2</sub> + N<sub>2</sub>) in air charged</p> <p>= 13.06 + 42.9 = 55.96 kg Mol. Wt. of air = 28.84</p> <p>Moles of air charged or supplied = <math>\frac{55.96}{28.84} = 1.94 \text{ kmol}</math></p>	<p>1</p> <p>1</p> <p>1</p>
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Theoretical O<sub>2</sub> required for 1.2068 kmol HCl charged, from the reaction

$$= \frac{1}{4} \times 1.2068 = 0.3017 \text{ kmol}$$

$$\text{Theoretical air required} = 0.3017 \times \frac{100}{21} = 1.44 \text{ kmol}$$

$$\% \text{ excess air} = \frac{\text{air supplied} - \text{air theoretically required}}{\text{air theoretically required}} \times 100$$

$$= \frac{1.94 - 1.44}{1.44} \times 100 = 34.72 \quad \text{..... Ans. (a)}$$

**Composition of Gases Entering the Reactor :**

Component	Quantity in kg	Weight%
HCl	44.05	44.05
O <sub>2</sub>	13.06	13.06
N <sub>2</sub>	42.90	42.90
<b>Total</b>	<b>100.00</b>	<b>100.00</b>

..... Ans. (b)

3-ii

**SOLUTION :**

**BASIS :** 15000 mol /h of N<sub>2</sub> – H<sub>2</sub> mixture.

Molal flowrate of gas mixture = 15 kmol /h

$$X_{\text{N}_2} = 25 / 100 = 0.25$$

$$X_{\text{H}_2} = 75 / 100 = 0.75$$

$$C_p^{\circ} \text{ mix} = \sum C_p^{\circ} \text{ mix} \cdot X_i$$

$$= X_{\text{N}_2} C_p^{\circ} \text{ N}_2 + X_{\text{H}_2} C_p^{\circ} \text{ H}_2$$

$$= 0.25 (29.5909 - 5.41 \times 10^{-3} T + 13.1829 \times 10^{-6} T^2 -$$



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	$4.968 \times 10^{-9} T^3) + 0.75 (28.6105 + 1.0194 \times 10^{-3} T - 0.1476 \times 10^{-6} T^2 + 0.769 \times 10^{-9} T^3)$ $= 28.8556 - 0.588 \times 10^{-3} T + 3.185 \times 10^{-6} T^2 - 0.6652 \times 10^{-9} T^3$ <p>Q = Heat transferred</p> $= n \int_{T_1}^{T_2} C_p^{\circ} \text{mix} \cdot dT$ $= n \int_{T_1}^{T_2} (28.8556 - 0.588 \times 10^{-3} T + 3.185 \times 10^{-6} T^2 - 0.6652 \times 10^{-9} T^3) dT$ $= n [28.8556 (T_2 - T_1) - 0.588/2 \times 10^{-3} (T_2^2 - T_1^2) + 3.185 \times 10^{-6}/3 (T_2^3 - T_1^3) - 0.6652 \times 10^{-9}/4 (T_2^4 - T_1^4)]$ <p>Where ,n = 15 kmol / h , T<sub>1</sub> = 298 K , T<sub>2</sub> = 473 K.</p> $Q = 15 [28.8556 (473 - 298) - 0.5207/2 \times 10^{-3} (473^2 - 298^2) + \frac{3.185 \times 10^{-6}}{3} (473^3 - 298^3) - \frac{0.6652 \times 10^{-9}}{4} (473^4 - 298^4)]$ $= 15 (5049.73 - 35.13 + 84.25 - 7.01)$	<p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p>
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	$= 76377.6 \text{ kJ/h} = 21.21 \text{ kJ/s} = 21.21 \text{ kW} \quad \dots\text{Ans}$	1
3-iii	Basis: 26.6 lit $\text{NO}_2$ $PV=nRT$ $n = PV/ RT$ $= 80 * 0.0266/ 8.314 * 298 = 8.6 * 10^{-4} \text{ kmol} = 0.86 \text{ mol}$ $2\text{NO}_2 \text{ ---} \rightarrow \text{N}_2\text{O}_4$ Let x moles of $\text{N}_2\text{O}_4$ in final mixture $\text{NO}_2$ reacted = 2x $\text{NO}_2$ remaining = $(0.86 - 2x)$ . Total moles = $x + 0.86 - 2x$ $= 0.86 - x$ $P_1/P_2 = n_1/n_2$ $80/ 66.662 = 0.86/(0.86-x)$ Solving, $x = 0.1434 \text{ mol}$ Final moles = $0.86 - 0.1434 = 0.7166 \text{ mol}$ Mol fraction of $\text{N}_2\text{O}_4 = 0.1434/0.7166 = 0.2$ Partial pressure of $\text{N}_2\text{O}_4 = 0.2 * 66.662 = 13.33 \text{ kPa}$	1 1 1 1 1 1 1 1 1 1 1 1
4	Any 2	16
4-i	<b>SOLUTION :</b> <b>BASIS :</b> 1000 kg of desired mixed acid.	1



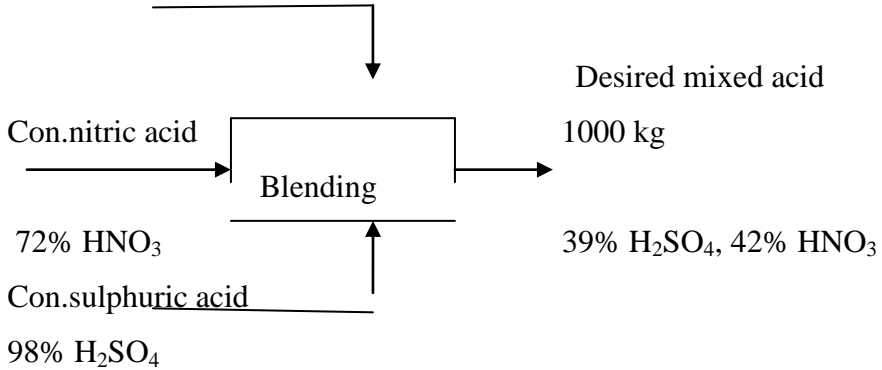
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<p>Waste acid, 30 % H<sub>2</sub>SO<sub>4</sub>, 35% HNO<sub>3</sub></p>  <p>Desired mixed acid 1000 kg</p> <p>39% H<sub>2</sub>SO<sub>4</sub>, 42% HNO<sub>3</sub></p>	1
<p><b>Block diagram for fortifying waste acid with concentrated acids</b></p> <p>Let x, y and z be the kg of waste acid , concentrated sulphuric acid and concentrated nitric acid required to make 1000 kg desired acid.</p>	1
<p><b>Overall material Balance:</b></p> $x + y + z = 1000 \dots (i)$	1
<p><b>Material Balance of H<sub>2</sub>SO<sub>4</sub> :</b></p> $0.3 x + 0.98 y = 0.39 \times 1000 \dots (ii)$ $0.3 x + 0.98 y = 390$ $Y = (390 - 0.3 x) / 0.98$ $\therefore Y = 397.96 - 0.306 x \dots (iii)$	1
<p><b>Material Balance of HNO<sub>3</sub> :</b></p> $0.35 x + 0.72 z = 0.42 \times 1000$ $0.35 x + 0.72 z = 420 \dots (iv)$ $z = (420 - 0.35 x) / 0.72$ $\therefore z = 583.3 - 0.486 x \dots (v)$	
<p>Put values of y and z from equations (iii) and (v) in eqn (i) and solve for x.</p> $\therefore x + (397.96 - 0.306 x) + (583.3 - 0.486 x) = 1000$	



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	<p style="text-align: right;"><math>\therefore x = 90.1 \text{ kg}</math></p> <p>We have , <math>y = 397.96 - 0.306 x</math> <math>= 397.96 - 0.30 \times 90.1</math></p> <p><math>\therefore y = 370.4 \text{ kg}</math></p> <p>We have , <math>z = 583.3 - 0.486 x</math> <math>= 583.3 - 0.486 \times 90.1</math></p> <p><math>\therefore z = 539.5 \text{ kg}</math></p> <p>Amount of waste acid required = <b>90.1 kg</b></p> <p>Amount of concentrated sulphuric acid required = <b>370.4 kg</b></p> <p>Amount of concentrated nitric acid require = <b>539.5 kg</b> ....Ans</p>	<p>1</p> <p>2</p>
4-ii	<p><b>Basis :</b> 100 Kmol of feed</p> <p>Feed contains 60 kmol A , 30 kmol B and 10 kmol inerts</p> <p>Let X be the kmol of A reacted by reaction :</p> $2A + B \rightarrow C$ <p>From reaction <math>2 \text{ kmol A} = 1 \text{ kmol B} = 1 \text{ kmol C}</math></p> <p><math>B \text{ reacted} = (1/2) * X = 0.5 X \text{ kmol}</math></p> <p><math>C \text{ formed} = (1/2) * X = 0.5 X \text{ kmol}</math></p> <p>Material Balance of A give</p> <p><math>A \text{ unreacted} = (60 - X) \text{ kmol}</math></p> <p><b>Material Balance of Inerts :</b></p> <p><math>\text{Inerts in feed} = \text{Inert in product} = 10 \text{ kmol}</math></p> <p><math>C \text{ formed} = (1/2) * X = 0.5 X \text{ kmol}</math></p> <p><math>B \text{ unreacted} = (30 - 0.5 X) \text{ kmol}</math></p> <p>Total moles of product stream = <math>(60 - X) + (30 - 0.5X) + 10 = 0.5X</math> <math>= 100 - X \text{ Kmol}</math></p> <p>Mole % of A in product stream = 2%</p>	<p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p>



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	<p>Kmol A in product stream</p> <p>Mole % of A = ----- * 100</p> <p>Total kmol of product stream</p> <p>60 - X</p> <p>2 = ----- * 100</p> <p>100 - X</p> <p>X = 59.184 kmol = amount of A reacted</p> <p>Kmol A reacted</p> <p>Conversion of A = ----- * 100</p> <p>Total kmol of A feed</p> <p>59.184</p> <p>Conversion of A = ----- * 100 = <b>98.64 % ----- Ans</b></p> <p>60</p>	<p>1</p> <p>1</p> <p>1</p> <p>1</p>
4-iii	<p>Basis: 10000 kg/hr of feed</p> <p>10000 kg/hr solution 20 % methanol</p> <p style="text-align: center;"> </p> <p>Overall balance is</p> <p>10000 = X + Y .....(1)</p> <p>Individual balance for CH<sub>3</sub>OH is</p> <p>0.2*10000 = 0.98X + 0.01*Y .....(2)</p>	<p>1</p> <p>1</p> <p>1</p> <p>1</p>



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	<p>Solving the equations</p> <p><b>X= 1958.76 Kg/hr</b></p> <p><b>Y= 8041.24 kg/hr</b></p> <p>Mass flow rate of distillate = <b>1958.76 Kg/hr</b></p> <p>Mass flow rate of bottom product = <b>8041.24 kg/hr</b></p> <p>Methanol in Waste solution = <math>0.01 * 8041 = 80.41 \text{ Kg/hr}</math></p> <p>Methanol in feed = <math>0.2 * 10000 = 2000 \text{ Kg/hr}</math></p> <p style="text-align: center;">Methanol in Waste Solution</p> <p>% loss of Methanol = <math>\frac{\text{Methanol in Waste Solution}}{\text{Methanol in Waste Solution}} * 100</math></p> <p style="text-align: center;">80.41</p> <p>% loss of Methanol = <math>\frac{\text{-----}}{2000} * 100</math></p> <p><b>% loss of Methanol = 4.02 % ----- ans. (b)</b></p>	<p>1</p> <p>1</p> <p>1</p> <p>1</p>
<b>5</b>	<b>Any 2</b>	<b>16</b>
5-i	<p><b>Basis : 5000 kg of slurry to be handled</b></p> <div style="border: 1px solid black; padding: 10px; margin: 10px 0;"> <p style="text-align: center;"> </p> </div> <p>Let X be the kg of wet solids( desired product ) and Y be the kg of filtrate per batch</p> <p><b>Overall Material balance</b></p> <p style="text-align: center;"><math>X + Y = 5000 \text{ -----(1)}</math></p> <p><b>Solids Balance:</b></p>	<p>1</p> <p>1</p>





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	<p>Solids in slurry = Solids in product + Solids in filtrate</p> $0.25 \times 5000 = 0.92 X + (200/10^6) Y \text{ ----- (2)}$ <p>From equation (1) <math>Y = 5000 - X</math></p> <p>Equation (2), we get,</p> $0.25 \times 5000 = 0.92 X + (200/10^6) (5000 - X)$ <p>By solving we get,</p> $X = 1358 \text{ kg}$ $Y = 5000 - 1358 = 3642 \text{ kg}$ <p>100 kg desired product takes one hour of operation</p> <p><b>Time required to process complete batch = <math>(1358/100) \times 1 = 13.58 \text{ hr}</math></b></p> <p>Solid in filtrate = Solid loss per batch</p> $= (200/10^6) \times 3642 = 0.73 \text{ kg}$ <p><b>Solid loss per batch = 0.73 kg</b></p>	<p>1</p> <p>2</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p>
5-ii	<p><b>Basis</b> : 1 katom of sulphur burnt</p> <p><b>Reactions</b> :</p> $S + O_2 \rightarrow SO_2$ $S + (3/2) O_2 \rightarrow SO_3$ <p>From the reaction - 2 : 1katom S = 1.5 kmol O<sub>2</sub></p> <p>Stoichiometric requirement of O<sub>2</sub> by reaction 2 = <math>(1.5/1) \times 1 = 1.5 \text{ kmol}</math></p> <p>Stoichiometric air requirement = <math>1.5 \times (100/21) = 7.14 \text{ kmol}</math></p> <p>Air supplied to burner = <math>7.14 \times [1 + (20/100)] = 8.57 \text{ kmol}</math></p> <p>O<sub>2</sub> in supplied air = <math>8.57 \times 0.21 = 1.8 \text{ kmol}</math></p> <p>N<sub>2</sub> in supplied air = <math>8.57 \times 0.79 = 6.77 \text{ kmol}</math></p> <p>30% of sulphur fed to burner is oxidized to SO<sub>3</sub> by reaction -2 and 70 % of sulphur fed to burner is oxidized to SO<sub>2</sub> by reaction 1</p> <p>Sulphur burnt by reaction 1 = <math>0.7 \times 1 = 0.7 \text{ katom}</math></p> <p>Sulphur burnt by reaction 2 = <math>0.3 \times 1 = 0.3 \text{ katom}</math></p>	<p>1</p> <p>1</p> <p>1</p>



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	<p>O<sub>2</sub> reacted by reaction 1 = (1/1) x 0.7 = 0.7 kmol  O<sub>2</sub> reacted by reaction 2 = (1.5/1) x 0.3 = 0.45 kmol  O<sub>2</sub> reacted totally = 0.7 + 0.45 = 1.15 kmol  O<sub>2</sub> unreacted = O<sub>2</sub> feed - O<sub>2</sub> reacted  = 1.8 – 1.15 = 0.65 kmol  N<sub>2</sub> in supplied air = N<sub>2</sub> in gas leaving the burner  = 0.77 kmol   SO<sub>2</sub> produced by reaction 1 = (1/1) x 0.7 = 0.7 kmol  SO<sub>3</sub> produced by reaction 2 = (1/1) x 0.3 = 0.3 kmol</p> <p><b>Composition of gas Leaving the Burner :</b></p> <table border="1" style="width: 100%; border-collapse: collapse; margin: 10px 0;"> <thead> <tr> <th style="text-align: center;">Component</th> <th style="text-align: center;">Quantity in kmol</th> <th style="text-align: center;">Mole %</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">O<sub>2</sub></td> <td style="text-align: center;">0.65</td> <td style="text-align: center;">7.72</td> </tr> <tr> <td style="text-align: center;">N<sub>2</sub></td> <td style="text-align: center;">6.77</td> <td style="text-align: center;">80.40</td> </tr> <tr> <td style="text-align: center;">SO<sub>2</sub></td> <td style="text-align: center;">0.7</td> <td style="text-align: center;">8.31</td> </tr> <tr> <td style="text-align: center;">SO<sub>3</sub></td> <td style="text-align: center;">0.3</td> <td style="text-align: center;">3.57</td> </tr> <tr> <td style="text-align: center;">Total</td> <td style="text-align: center;">8.42</td> <td style="text-align: center;">100</td> </tr> </tbody> </table> <p>SO<sub>2</sub> in gas leaving burner = 0.7 x 64 = 44.8 kg  SO<sub>2</sub> in gas leaving burner = 0.3 x 80 = 24 kg  O<sub>2</sub> in gas leaving burner = 0.65 x 32 = 20.8 kg  N<sub>2</sub> in gas leaving burner = 0.77 x 28 = 189.56 kg  Weight of gas leaving burner = 4.8+24+20.8 +189.56 = 279.16 kg   279.16 kg of gas is produced from 01 katom of S or 32 kg of S</p> <p><b>Weight of gas per kg of Sulphur burnt = (279.16/32) x 1  = 8.72 kg</b></p>	Component	Quantity in kmol	Mole %	O <sub>2</sub>	0.65	7.72	N <sub>2</sub>	6.77	80.40	SO <sub>2</sub>	0.7	8.31	SO <sub>3</sub>	0.3	3.57	Total	8.42	100	1
Component	Quantity in kmol	Mole %																		
O <sub>2</sub>	0.65	7.72																		
N <sub>2</sub>	6.77	80.40																		
SO <sub>2</sub>	0.7	8.31																		
SO <sub>3</sub>	0.3	3.57																		
Total	8.42	100																		
	<p><b>5-iii</b> <b>Basis:</b> 32 kg of Oxygen gas   Q= Heat added</p>																			



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	$T_2$ $= n \int_{T_1}^{T_2} C_p dT$ $= n \int_{T_1}^{T_2} [ 26.0257 + 11.7551 \times 10^{-3} T - 2.3426 \times 10^{-6} T^2 + 0.5623 \times 10^{-9} T^3 ] dT$ $= n [ 26.0257 (T_2 - T_1) + (11.7551 \times 10^{-3} / 2)(T_2^2 - T_1^2) - (2.3426 \times 10^{-6} / 3) (T_2^3 - T_1^3) - (0.5623 \times 10^{-9} / 4) (T_2^4 - T_1^4) ]$ <p>Where <math>n = 32/32 = 1</math> kmol, <math>T_2 = 488</math> K, <math>T_1 = 313</math> K</p> $= 1 [ 26.0257 (488 - 313) + (11.7551 \times 10^{-3} / 2)(488^2 - 313^2) - (2.3426 \times 10^{-6} / 3) (488^3 - 313^3) - (0.5623 \times 10^{-9} / 4) (488^4 - 313^4) ]$ $= 1 [ (-4554.5) + (-823.89) + 66.80 + 6.62 ]$ <p><b>Q = - 5304.97 KJ (heat removed) ----- Ans.</b></p>	<p>1</p> <p>1</p> <p>2</p> <p>2</p> <p>2</p>
<b>6</b>	<b>Any 4</b>	<b>16</b>
6-i	<p><b>Basis:</b> 1 mol of ethylene gas</p> $C_2H_4(g) + \frac{1}{2} O_2 \longrightarrow C_2H_4O(g)$ <p><math>\Delta H_R^\circ =</math> Standard heat of reaction</p> $= [ \sum \Delta H_f^\circ ]_{\text{product}} - [ \sum \Delta H_f^\circ ]_{\text{reactant}}$ $= [ (1 \times \Delta H_f^\circ)_{C_2H_4O(g)} ] - [ (1 \times \Delta H_f^\circ)_{C_2H_4(g)} + (1/2 \times \Delta H_f^\circ)_{O_2} ]$ $= [ 1 \times (-52.63) ] - [ 1 \times (52.50) + 1/2 \times (0.0) ]$	<p>1</p> <p>1</p>





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6-iii	<p><b>Basis:</b> 1 kg of air in gas inlet to absorption system.</p>	
	<div data-bbox="285 556 1089 747" data-label="Diagram"> </div> <p>Ammonia in inlet gas to absorption system = <math>(0.2/1) \times 1 = 0.2</math> kg  Air is inert as far as absorption operation is concerned  Air in gas leaving the system = Air in inlet gas = 01 kg  NH<sub>3</sub> in gas leaving the system = <math>(0.004/1) \times 1 = 0.004</math> kg</p> <p><b>Material Balance of NH<sub>3</sub></b></p> <p>NH<sub>3</sub> in gas entering = NH<sub>3</sub> in gas leaving + NH<sub>3</sub> absorbed</p> $0.2 = 0.004 + \text{NH}_3 \text{ absorbed}$ <p>NH<sub>3</sub> absorbed = <math>0.2 - 0.004 = 0.196</math> kg</p> $\% \text{ recovery of NH}_3 = \frac{\text{NH}_3 \text{ absorbed}}{\text{NH}_3 \text{ in Inlet gas}} \times 100$ $\% \text{ recovery of NH}_3 = \frac{0.196}{0.2} \times 100$ <p><b>% recovery of NH<sub>3</sub> = 98 % ----- ans.</b></p>	<p>1</p> <p>1</p> <p>1</p> <p>1</p>
6-iv	<p><b>Basis :</b> 100 Kmol of ethylene fed to a reactor.</p>	



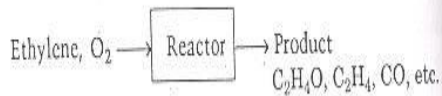
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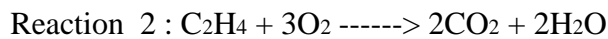
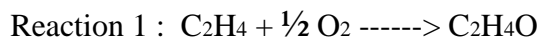
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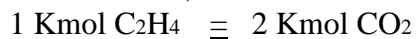
1

Amount of C<sub>2</sub>H<sub>4</sub>O produced = 80 KmoleAmount of CO<sub>2</sub> produced = 10 KmoleC<sub>2</sub>H<sub>4</sub> reacted to produce C<sub>2</sub>H<sub>4</sub>O by Reaction 1

$$= \frac{1}{1} * 80 = 80 \text{ Kmole}$$

1

From Reaction 2,

C<sub>2</sub>H<sub>4</sub> reacted to produce 10 Kmole CO<sub>2</sub> by reaction 2

$$= \frac{1}{2} * 10 = 5 \text{ Kmole}$$

C<sub>2</sub>H<sub>4</sub> totally reacted = C<sub>2</sub>H<sub>4</sub> reacted by reaction 1 +C<sub>2</sub>H<sub>4</sub> reacted by reaction 2

$$= 80 + 5 = 85 \text{ Kmole}$$

$$\% \text{ conversion of C}_2\text{H}_4 = \frac{\text{C}_2\text{H}_4 \text{ totally reacted}}{\text{C}_2\text{H}_4 \text{ totally feed}} * 100$$

1

$$= \frac{85}{100} * 100 = 85 \%$$

**% conversion of C<sub>2</sub>H<sub>4</sub> = 85 % ----- ans. (a)**



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	<p style="text-align: center;">Kmol C<sub>2</sub>H<sub>4</sub> reacted to Produce C<sub>2</sub>H<sub>4</sub>O</p> $\% \text{ yield of C}_2\text{H}_4\text{O} = \frac{\text{Kmol C}_2\text{H}_4\text{O produced}}{\text{Kmol C}_2\text{H}_4 \text{ totally reacted}} * 100$ $= \frac{80}{85} * 100 = 94.12 \%$ <p style="text-align: center;"><b>% yield of C<sub>2</sub>H<sub>4</sub>O = 94.12% ----- ans. (b)</b></p>	1
6-v	<p><b>Basis:</b> 100 kmol of ethanol fed to reactor.</p> <p><b>Reaction :</b> C<sub>2</sub>H<sub>5</sub>OH ----- &gt; CH<sub>3</sub>CHO +H<sub>2</sub></p> <p>Amount of CH<sub>3</sub>CHO produced is 45 kmol.</p> <p>From the reaction ,</p> <p style="margin-left: 40px;">1 Kmole CH<sub>3</sub>CHO = 1 Kmole C<sub>2</sub>H<sub>5</sub>OH</p> <p style="margin-left: 40px;">1 Kmole CH<sub>3</sub>CHO = (1/1) * 45 Kmole C<sub>2</sub>H<sub>5</sub>OH</p> <p style="margin-left: 40px;">= 45 Kmole C<sub>2</sub>H<sub>5</sub>OH</p> <p>Moles of C<sub>2</sub>H<sub>5</sub>OH reacted = 45 Kmole</p> $\% \text{ conversion of C}_2\text{H}_5\text{OH} = \frac{\text{Moles of C}_2\text{H}_5\text{OH reacted}}{\text{Moles of C}_2\text{H}_5\text{OH charged}} * 100$ $= \frac{45}{100} * 100$ <p style="text-align: center;"><b>% conversion of C<sub>2</sub>H<sub>5</sub>OH = 45 % ----- ans.</b></p>	1 1 1
6-vi	<b>Basis :</b> 1 hr of operation	



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Quantity of wet lumber handled = $(2000/1) \times 1 = 2000$ kg	
Dried material in lumber = $(1 - 0.05) \times 2000 = 1900$ kg	1
Dried material in dried lumber = 1900 kg	
Dried lumber contain 1 % water	
Dried lumber = $[100/(100-1)] \times 100 = 1919.2$ kg	
Let X be the kg of dry air in air entering dryer	1
Air entering dryer = $(100/99.5) X = 1.005 X$ kg	
<b>Water balance :</b>	
Water in wet lumber – Water in dried lumber = Water added in air	1
$0.05 \times 2000 - 0.01(1919.2) = [(0.02/0.98) X] - [(0.005/0.995) X]$	
By solving we get,	
$X = 5254$ kg	
Air required = $1.005 (5254) = 5280.3$ kg	1
<b>Air required to be fed to dryer = 5280.3 Kg ----- ans.</b>	