

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION

Summer-13 EXAMINATION

Model Answer

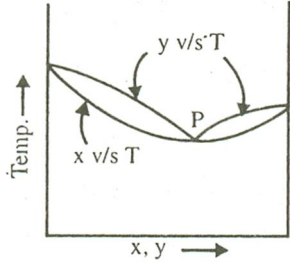
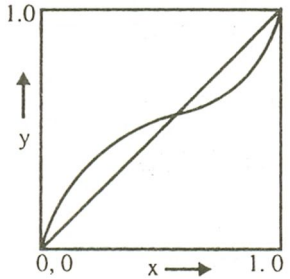
Subject & code: MTO(12297)

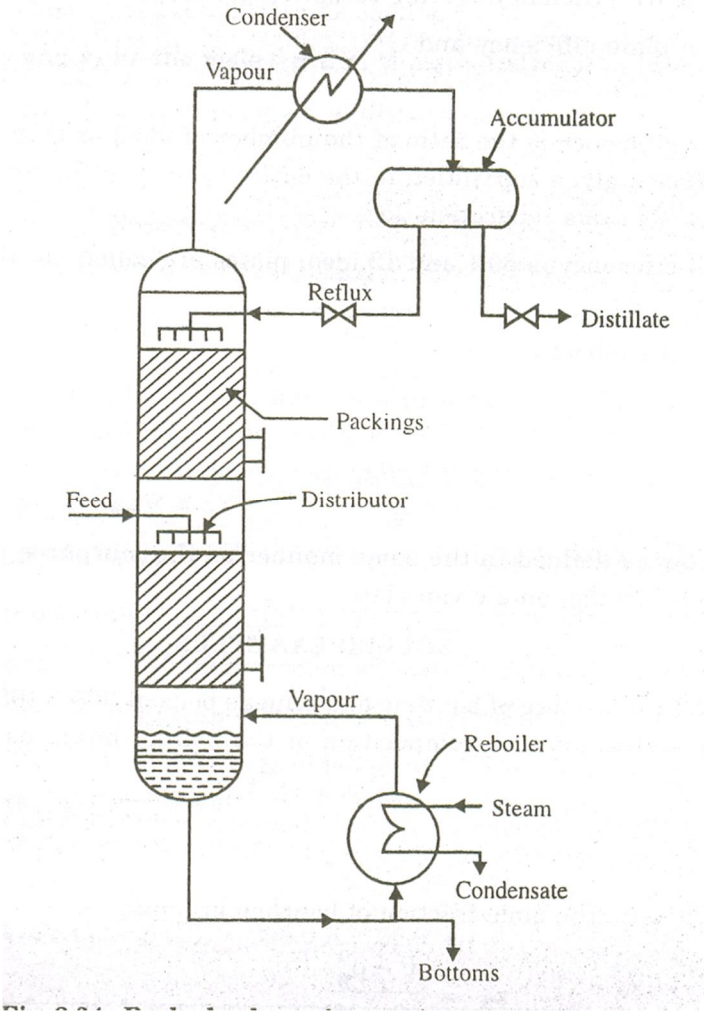
Important instructions to examiners :

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 i	<b>Steady state equimolar counter diffusion:</b>		4

	$N_A = J_A + x_A (N_A + N_B)$ $= -D_{AB} \frac{dC_A}{dz} + \frac{C_A}{c} (N_A + N_B)$ <p>For ideal gas <math>P_A = C_A RT</math></p> $C_A = \frac{P_A}{RT}$ $dC_A = \frac{dP_A}{RT}$ $c = \frac{P}{RT}$ <p>putting values of <math>C_A</math>, <math>dC_A</math> &amp; <math>c</math></p> $N_A = -D_{AB} \frac{dP_A}{RT} \frac{1}{dz} + \frac{P_A/RT}{P/RT} (N_A + N_B)$ <p>For equimolar counter diffusion, <math>N_A = -N_B</math></p> $\therefore N_A = -\frac{D_{AB}}{RT} \frac{dP_A}{dz}$ <p>if <math>D_{AB}</math> is constant, this can be integrated</p> $N_A \int_{z_1}^{z_2} dz = -\frac{D_{AB}}{RT} \int_{P_{A1}}^{P_{A2}} dP_A$ $N_A (z_2 - z_1) = -\frac{D_{AB}}{RT} (P_{A2} - P_{A1})$ $N_A z = +\frac{D_{AB}}{RT} (P_{A1} - P_{A2})$ $N_A = \frac{D_{AB}}{RTz} (P_{A1} - P_{A2})$	1	
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ii.			

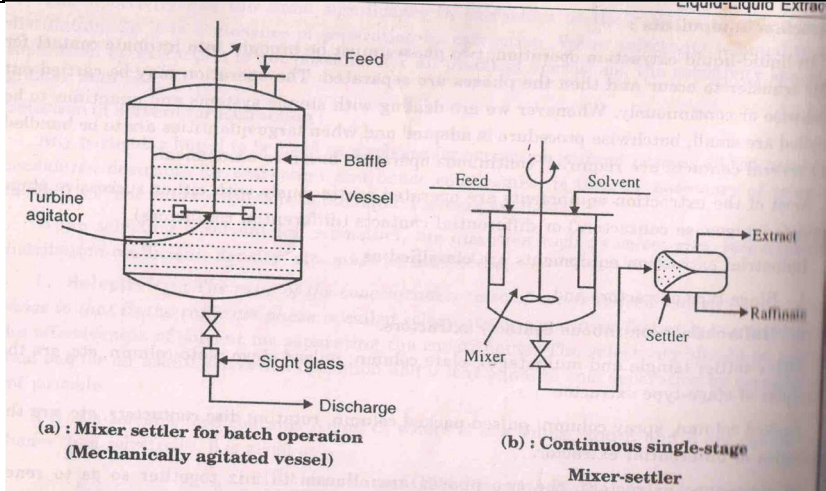
	 <p><b>Boiling point diagram for minimum boiling azeotrope</b></p>	2	4
	 <p><b>Equilibrium diagram for minimum boiling azeotrope</b></p>	2	
iii.	<p><b>Wet Bulb Temperature:</b> The temperature recorded by a thermometer whose bulb is kept wet by wrapping with a wet cotton in the open air is called dry bulb temperature.</p> <p><b>Dry bulb temperature:</b> The temperature recorded by a thermometer whose bulb is kept dry is called dry bulb temperature.</p> <p><b>Critical Moisture content:</b> The moisture content of a material at which the constant rate period ends and the falling rate period starts is called critical moisture content.</p> <p><b>Equilibrium moisture content:</b> The moisture content of a solid material that is in thermodynamic equilibrium with its vapour in the gas phase under specified humidity and temperature of gas is called equilibrium moisture content.</p>	1 1 1 1	4

		3	4
iv	 <p><b>Packed column for continuous distillation.</b></p> <p>Names of tower packings:</p> <ol style="list-style-type: none"> <li>1. Pall ring</li> <li>2. Lessing ring</li> <li>3. Raschig ring</li> <li>4. Cross partition ring</li> <li>5. Intalox saddle</li> </ol>	1	

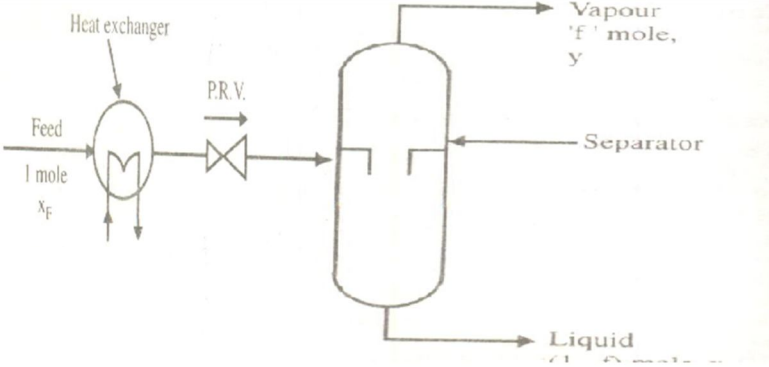
1 B	<b>Fick's law of diffusion:</b>	2	6
i	It states that the flux of a diffusing component A in z direction in a binary mixture of A and B is proportional to the molar concentration gradient. $J_A = -D_{AB} dC_A/dz$ Reynolds Analogy between heat and mass transfer $h/C_p \cdot u \cdot \rho = kc/u$ Complete Reynolds analogy $h/C_p \cdot u \cdot \rho = kc/u = f/2$	2  1  1	
1.B	<b>Selection criteria for solvent selection in liquid-liquid extraction:</b>	1	6
.ii	<ol style="list-style-type: none"> <li><b>1. Selectivity:</b> The ratio of concentration ratio of solute to feed solvent in extract phase to that in raffinate phase is called selectivity factor. It is the measure of effectiveness of solvent for separating the constituents.</li> <li><b>2. Recoverability:</b> As solvent should be recovered for reuse frequently by distillation, it should not form an azeotrope with extracted solute and for low cost recovery, relative volatility should be high.</li> <li><b>3. Distribution coefficient:</b> Higher values are desirable as less solvent will then be required for given extraction duty.</li> <li><b>4. Density:</b> The difference in densities of saturated liquid phases should be larger for physical separation.</li> <li><b>5. Insolubility of solvent:</b> The solvent insoluble in original liquid solvent should be preferred and it should have high solubility for solute to be extracted, then small amounts of solvent are required.</li> <li><b>6. Chemical Stability:</b> The solvent should be stable chemically and inert towards other components and should not be corrosive.</li> <li><b>7. Cost:</b> The solvent should be cheap.</li> <li><b>8.</b> The solvent should be non toxic, non flammable.</li> <li><b>9.</b> Solvent should have low viscosity, freezing point, vapor pressure for ease in handling and storage.</li> <li><b>10. Interfacial tension:</b> It should be high for coalescence of emulsions to occur more readily, as the same is of greater importance than</li> </ol>	mark for any six points	

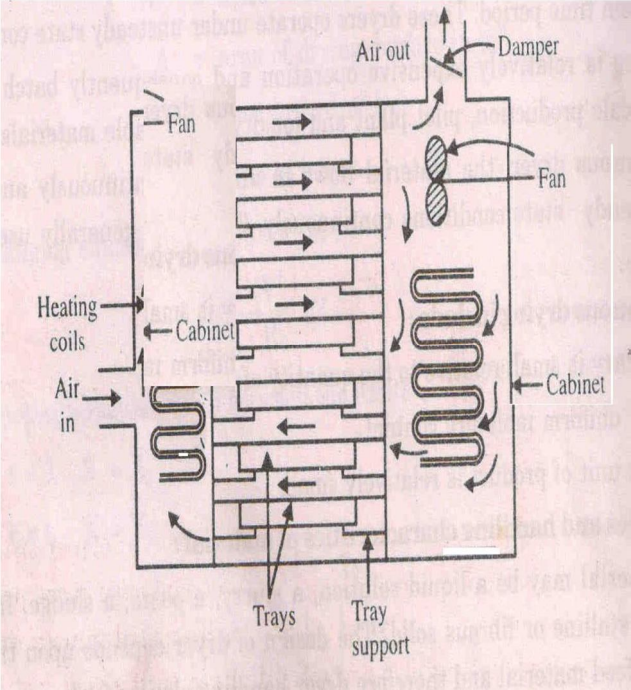


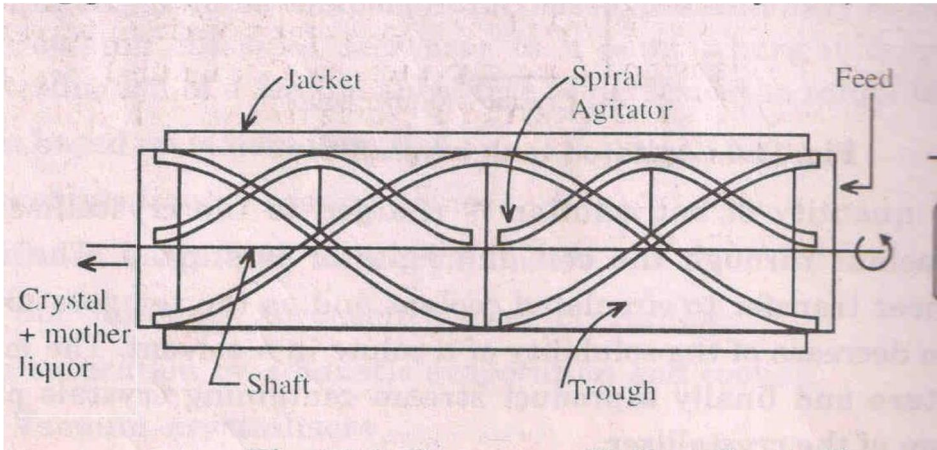


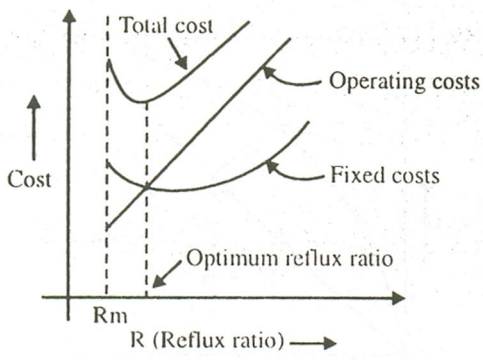
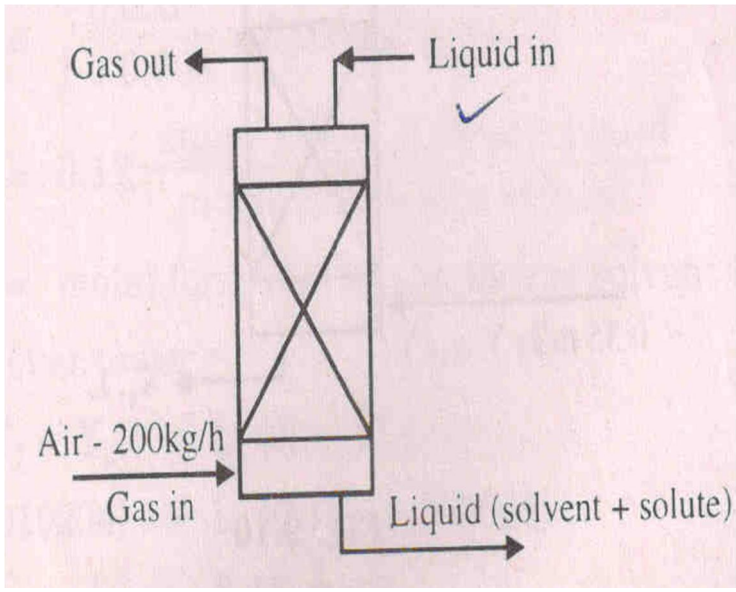
	liquid			each	
	Handling very small volume of liquid	Preferable	Not preferable		
	cost	Less	more		
3.c	 <p>(a) : Mixer settler for batch operation (Mechanically agitated vessel)</p> <p>(b) : Continuous single-stage Mixer-settler</p>			2	4
	<p>i) It consists of vertical tank incorporating a turbine or propeller agitator.</p> <p>ii) Feed solution to be extracted to be taken into an agitated vessel, then the required amount of solvent is added, and whole mass is agitated for predetermined time.</p> <p>iii) At the end of this, two phases are formed, one is extract phase and other is raffinate phase which are then separated.</p>			2	
3.d	<p>Various methods of distillations are:</p> <p>i) Simple or differential distillation</p> <p>ii) Flash or equilibrium distillation</p> <p>iii) Fractionation or Rectification</p> <p>Flash distillation is carried out in a continuous manner. In this method, a liquid mixture is partially vaporized the vapor and liquid are allowed to attained equilibrium and finally withdrawn separately</p>			1	4
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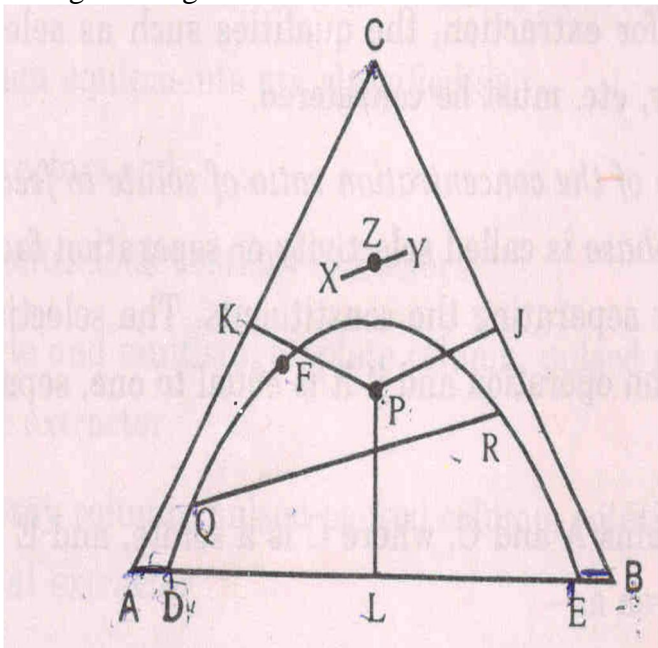


	 <p>The equation for flash distillation:</p> $y = -((1-f)/f) \cdot x + x_F/f$ <p>Where,</p> <p>x = the molefraction of more volatile component in liquid phase</p> <p>y = the molefraction of more volatile component in vapor phase</p> <p>f = fraction of liquid/feed vaporized</p>	1	
3.e	<p>solution: The flux for equimolar counter diffusion is given by,</p> $N_A = D_{AB} / RTz (p_{A1} - p_{A2})$ <p>Where, <math>D_{AB} = 6.75 \cdot 10^{-5} \text{ m}^2/\text{s}</math>, <math>R = 8.31451 \text{ m}^3 \cdot \text{kPa}/(\text{kmol} \cdot \text{K})</math></p> <p><math>T = 298 \text{ K}</math>, <math>z = 30\text{mm} = 0.03\text{m}</math></p> <p><math>p_{A1} = 55\text{kPa}</math>, <math>p_{A2} = 15 \text{ kPa}</math></p> $N_A = 6.75 \cdot 10^{-5} (55 - 15) / (8.31451 \cdot 298 \cdot 0.03)$ $= 3.63 \cdot 10^{-5} \text{ kmol}/(\text{m}^2 \cdot \text{s})$	1 2 1	4
4.a-i	<u>Tray Dryer:</u>		4

	 <p><b>Working:</b></p> <p>The material to be dried is spread over the trays and put into the cabinet then it is closed.</p> <p>Steam is continuously passed through the coil and the fan is started. Air is heated by heating coils, so its relative humidity decreases and the hot air then passes over the trays.</p> <p>The moisture is evaporated from the wet feed, gets added in air and finally air leaves the dryer through the outlet. The process is continued until the solids are dried.</p> <p><b>Advantages (any two):</b></p> <ol style="list-style-type: none"> <li>It is cheap and easy to construct.</li> <li>Low space requirement.</li> <li>Ease of cleaning.</li> <li>No loss of product during drying.</li> </ol>	1	
	<p>The material to be dried is spread over the trays and put into the cabinet then it is closed.</p> <p>Steam is continuously passed through the coil and the fan is started. Air is heated by heating coils, so its relative humidity decreases and the hot air then passes over the trays.</p> <p>The moisture is evaporated from the wet feed, gets added in air and finally air leaves the dryer through the outlet. The process is continued until the solids are dried.</p>	2	
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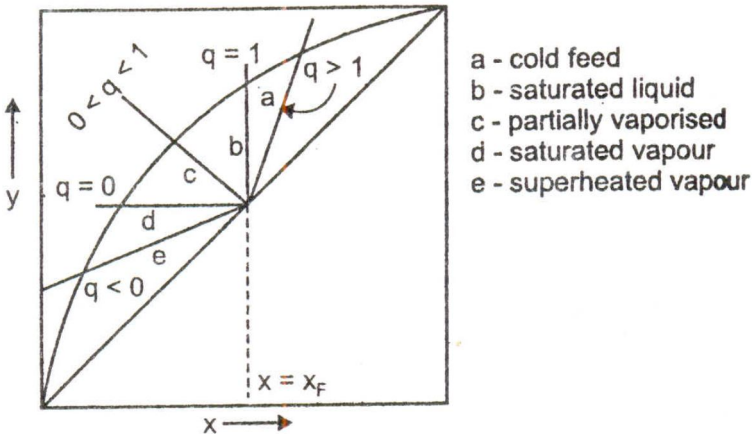
4.a-ii	<p><u>Swenson-walker Crystallizer:</u></p>  <ol style="list-style-type: none"> <li>It is the cooling type continuous jacketed trough crystallizer.</li> <li>It is an example of scrapped surface crystallizer.</li> <li>It contain slow speed long pitch agitator with a speed of 7 r.p.m. It helps to transport crystals from one point to another point and doesn't allow crystals to settle at the bottom.</li> <li>Feed is admitted at one end and mixture of crystals and mother liquor is removed from other end.</li> </ol>	2	4
4.a-iii	<ul style="list-style-type: none"> <li><b>Reflux ratio:</b> The ratio of quantity of liquid returned to the liquid that has taken out as distillate is known as reflux ratio (L/D).</li> <li><b>Total reflux:</b> It is the total overhead product which is returned back to the column. At total reflux no, of plates required is minimum with maximum purity.</li> <li><b>Minimum reflux:</b> At minimum reflux infinite no. of plates are required and purity also low and no product is obtained.</li> </ul> <p>Optimum reflux: The optimum ratio occurs at a point where sum of the fixed cost and operating cost is minimum. The optimum reflux ratio usually lies in the range of 1.1 to 1.5 times the minimum reflux ratio.</p>	1  1  1	4

		1	
4.A -iv	<p>Basis : 200kg/hr of air flow to absorption tower.</p>  <p> <math>X_1'</math> = NH<sub>3</sub> composition at bottom = 0.006 kg of NH<sub>3</sub>/kg of water  <math>X_2'</math> = NH<sub>3</sub> composition at top = 0.000013 kg of NH<sub>3</sub>/kg of water  <math>Y_1</math> = NH<sub>3</sub> composition in inlet gas to tower = 0.0084 kg of NH<sub>3</sub>/kg of inert gas  <math>Y_2</math> = NH<sub>3</sub> composition in outlet gas from tower = 0.0044 kg of NH<sub>3</sub>/kg of air  <math>L'</math> = mass flowrate of solute free solvent in kg/hr  <math>V'</math> = mass flowrate of solute free gas or air in kg/hr         </p>	1	4
		2	

	$V' (Y_1 - Y_2) = L' (X_1 - X_2)$ $200 (0.0084 - 0.0044) = L' (0.0006 - 0.0000013)$ $L' = 1336.22 \text{ kg/hr}$ <p>Mass flowrate of water = 1336.22 kg/hr</p>	1	
4.b -i	<p>Triangular diagram:</p>  <p>Where  A=diluent  B=solvent  C=solute</p> <p>Binodial curve: It represents two phase region that will split up into two layers in equilibrium with each other.</p> <p>Tie line: Tie line is a line which connects two phases in equilibrium with each other.</p> <p>Plait point: The plait point on binodial solubility curve represent a single phase where the length of tie line is zero.</p>	3	6
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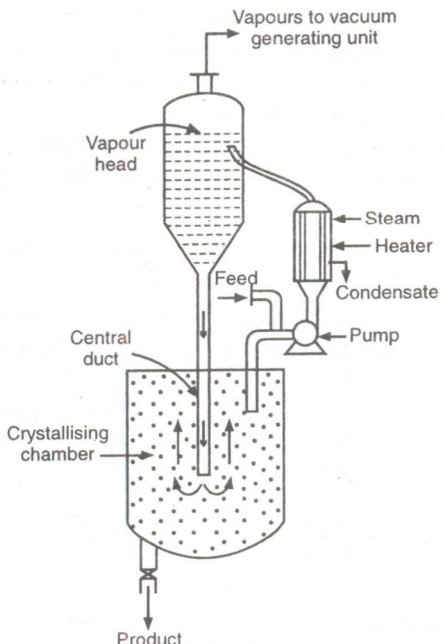


	<p>Y<sub>d,avg</sub>= mole fraction of heptanes in distillate.</p> <p>According to Rayleigh equation</p> <p><math>\ln(f/w)=\int dx/y-x</math> within limit x<sub>w</sub> to x<sub>f</sub> -----(1)</p> <p>LHS <math>\ln(f/w) =\ln(100/40)=0.916</math> -----(2)</p> <p>Generation of x-y data with the help of <math>\alpha=2.16</math></p> <p><math>Y=\sigma x/1+(\sigma-1)x</math></p> <p>As x<sub>f</sub>=0.4, generate the data upto x=0.5</p> <table><tr><td>X</td><td>0.05</td><td>0.1</td><td>0.2</td><td>0.3</td><td>0.40</td><td>0.50</td></tr><tr><td>Y</td><td>0.1</td><td>0.19</td><td>0.35</td><td>0.48</td><td>0.59</td><td>0.68</td></tr><tr><td>1/y-x</td><td>20</td><td>11.11</td><td>6.67</td><td>5.55</td><td>5.26</td><td>5.55</td></tr></table> <p>From eqn (1) &amp; (2)</p> <p><math>0.916= \text{Area} \times (0.1 \text{ unit}/2 \text{ cm}^2) \times (2 \text{ units}/1 \text{ cm}^2)</math></p> <p>Area =9.16 cm<sup>2</sup></p> <p>So measure the area under the curve from X<sub>F</sub>=0.40 till we get the area=9.16 cm<sup>2</sup></p> <p>This will give the value of <b>X<sub>w</sub>=0.22</b></p> <p>From material balance</p> <p><math>FX_F=DX_D+WX_W</math></p> <p>And find out <b>X<sub>D</sub>= 0.52</b></p>	X	0.05	0.1	0.2	0.3	0.40	0.50	Y	0.1	0.19	0.35	0.48	0.59	0.68	1/y-x	20	11.11	6.67	5.55	5.26	5.55	1	
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5.b	<p>Equation of feed line or q-line</p> <p><math>y=(-q/1-q)x+(x_f/1-q)</math></p> <p>where q is the measure of various thermal condition of feed.</p>	2	8																					

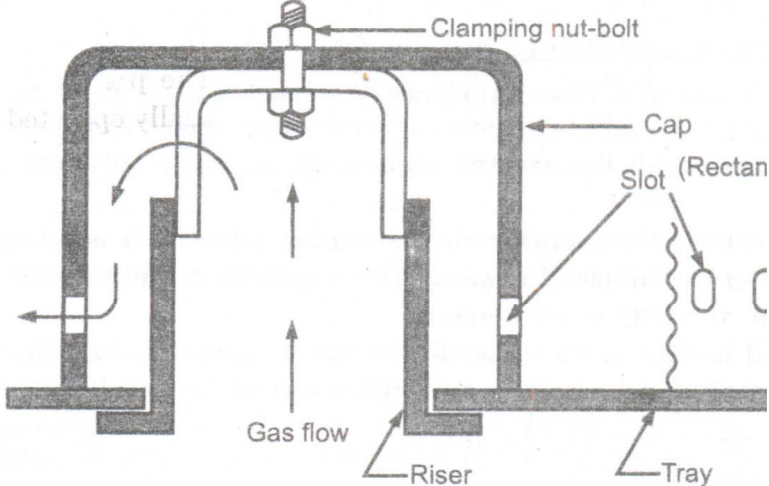
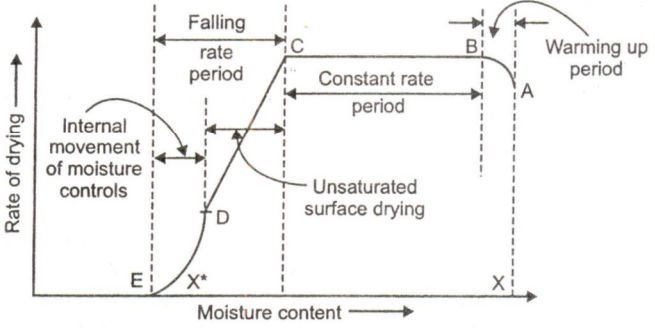
	 <p>a - cold feed b - saturated liquid c - partially vaporised d - saturated vapour e - superheated vapour</p> <p>2.15 : Effect of feed condition on feed line</p>	6	
5.c	<p>Mier's supersaturation theory:</p> <p>According to Mier's theory there is a definite relationship between the conc and temp at which crystals will spontaneously formed in a pure solution. This relationship is represented by the super solubility curve which is approximately parallel tp the solubility curve. The curve AB is the solubility curve and curve PQ is the super solubility curve. The curve AB represents maximum conc of solution which can be achieved by bringing solid-solute into eqm with liquid solvent. If a solution having the composition and temp indicated by point C is cooled in the direction shown by the arrow it first crosses the solubility curve AB and it is expected to start of crystallization. Actually if the process started with initially unseeded solution crystal formation will not begin until the solution is super cooled considerably passed the curve AB. According to Mier's theory , crystallization will start in the neighbourhood of the point D and the concentration of the solution then follows roughly along the curve DE. For an initially unseeded solution , the curve PQ represents the limit at which spontaneous nuclei formation begin and consequently, crystallization can start.</p> <p>Curve</p>	4	8



	<p>Two methods of supersaturation:</p> <p>a) By cooling a concentrated ,hot solution through indirect heat exchange.</p> <p>b) By evaporating a part of the solvent.</p>	2	
6.a	<p>a) <b>i) Daltons law</b> : it states that the total pressure exerted by gas/vapour mixture is equal to the sum of the partial pressures of components present in it, thus it expresses the additive nature of the partial pressure.</p> <p>Mathematically, for binary system</p> $P = p_A + p_B$ <p><b>ii) Gibbs phase rule:</b></p> <p>according to gibbs phase rule <math>F = C - P + 2</math></p> <p>where, F= Degree of freedom</p> <p>C= No of component</p> <p>P= no of phases</p>	2	4
6.b	<p>a) Oslo evaporative crystalliser</p>		4

	<p><b>Oslo Evaporative Crystalliser :</b></p> <p>In this crystalliser, supersaturation is generated/achieved by evaporation. It is circulating liquid evaporative crystalliser.</p> <p>It consists of a crystallising chamber containing a bed of forming and growir crystals, a circulating pump, an external heater for heating the solution with the help condensing steam and a vapour - head wherein reduced pressure is maintained by vacuum generating equipment. The heater is maintained under sufficient hydrostat head to avoid the boiling on the heating surface.</p>  <p><b>Fig. 6.7 : Oslo/Krystal Evaporative Crystalliser</b></p> <p>The solution from the crystallising chamber is pumped by a circulating pump on the suction side of which the feed solution forming a small part of the total circulating liquid is</p> <p>introduced into a heater, where it is heated by means of condensing steam (on the shell side of the heater) and then fed to a vapour head wherein some of the solution flashes into vapour resulting into some degree of supersaturation. The supersaturated solution is then returned to the bottom of the crystallising chamber through a central duct prolonged from the vapour head into the crystallising chamber. Nucleation takes place in the crystal bed which is maintained in a fluidised state by means of an upward flowing stream of liquid through the duct. The nuclei formed circulate with the mother liquor and once they grow sufficiently large they will be retained in the fluidised bed. When the crystals grow to a required size, they will be withdrawn as product from the bottom of the crystallising chamber as they will not be maintained in the fluidised bed by the circulation velocity.</p>	<p>1</p> <p>2</p> <p>1</p>
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6.c	<p>c) Higbie's penetration theory:</p> <ol style="list-style-type: none"> <li>1) As the time of exposure of fluid for mass transfer generally being short, development of the concentration gradient of film theory is not possible.</li> <li>2) The transfer is largely because of fresh material brought to the interface by the eddies.</li> <li>3) A process of unsteady state transfer occurs for a fixed period at the freshly exposed surface.</li> </ol> <p>Each fluid element (eddy) resides for the same length of time period at the surface. According to this theory, the mass transfer coefficient is proportional to the square</p>	4	4

6.d	<p><b>1. Bubble cap tray/plate :</b></p> <p>In case of bubble cap plate, gas/vapour flows through a riser, cap, moves downward through the annular space between the riser, it bubbles into a pool of liquid through a series of slots (opening at the periphery of the cap in its lower portion. The slots may be trapezoidal in shape.</p>  <p style="text-align: center;"><b>Fig. 2.29 : Bubble cap</b></p> <p>Bubble cap disperses the gas phase into liquid as fine bubbles. At low gas rates, the gas passes through the cap in a single column. As the gas rate increases, the gas flow is directed in a horizontal direction and then gas flows vertically upward through the cap in the form of bubbles. The bubble cap columns can be operated with efficiencies over a wide range of vapour and liquid flow rates.</p> <p>Bubble cap plates are now rarely used for new installations because of (i) relatively high cost and (ii) high pressure drop.</p>	2 4
6.e	<p>Fig. 5.3 shows the <b>rate of drying curve</b>. The section AB of the curve represents the warming up period during which the temperature of the solid is becoming equal to the temperature of drying air. From B to C, the curve is a straight line parallel to X-axis</p>  <p style="text-align: center;"><b>Fig. 5.3 : Typical rate of drying curve under constant drying conditions</b></p>	2 4

	<p>representing the constant rate of drying, thus the section BC is called the <b>constant rate period</b> during which the layer of water on the surface of solid is being evaporated. The rate of drying is constant from B to C as the drying takes place from a saturated surface. The section (CE) of the curve represents the <b>falling rate period</b> composed of the first falling rate period (CD) and the second falling rate period (DE). From point 'C' onwards some dry patches have started forming on the surface of the solid. The rate of drying decreases for the unsaturated portion and hence the rate for total surface decreases. The section CD of the curve represents the period corresponding to the zone of unsaturated surface drying. The moisture content at which the constant rate period ends and the drying rate starts to fall (i.e. at which unsaturated surface drying starts) is known as the <b>critical moisture content</b>. After point D, the surface of the solid is completely dry and now the internal movement of moisture starts coming to the surface and this is continued upto the point E, where the equilibrium is attained. The rate of drying over section DE is governed by the rate of internal moisture movement. The second falling rate period (DE) represents zone where the internal moisture movement controls.</p>	2	
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