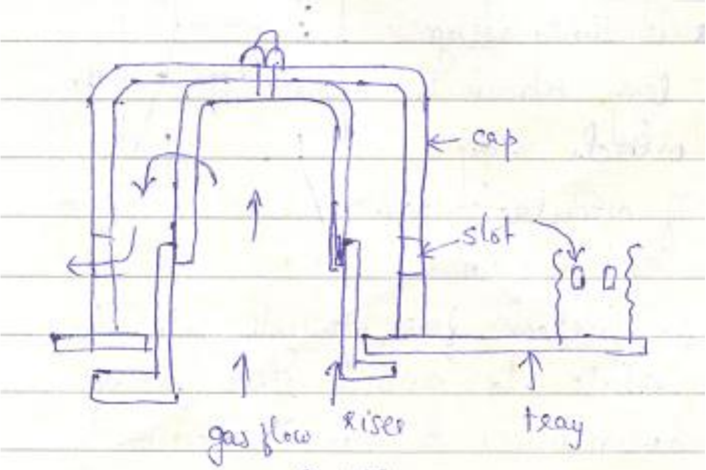
SUMMER-17 EXAMINATION

Model Answer

Important Instructions to examiners:

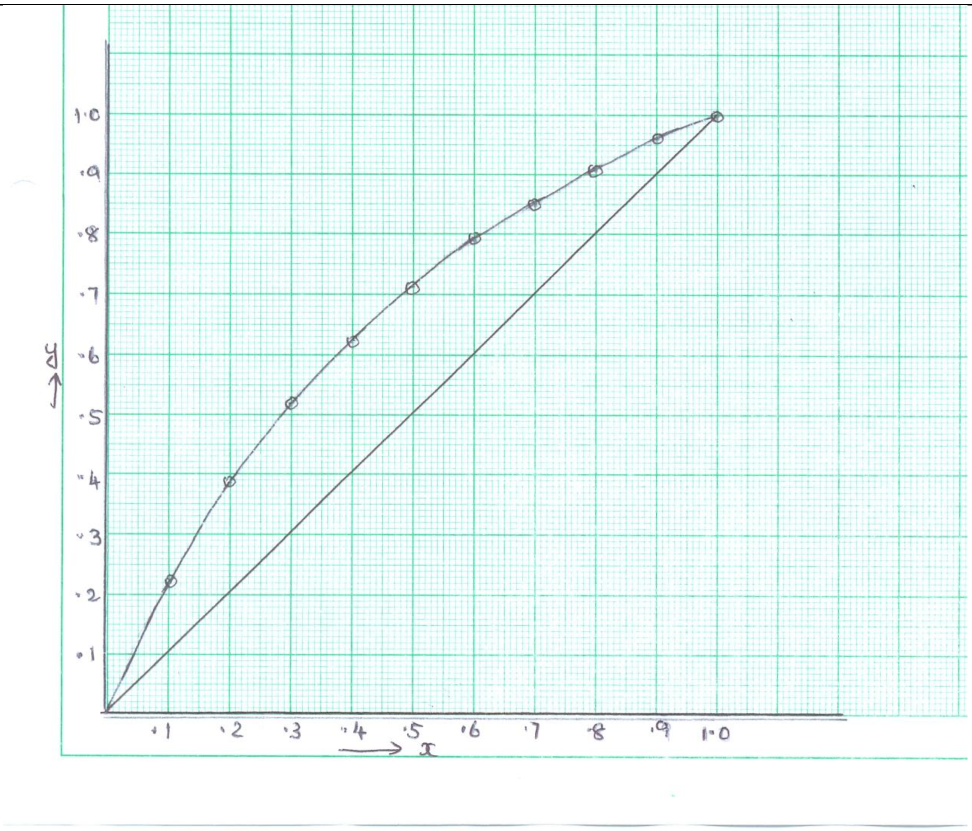
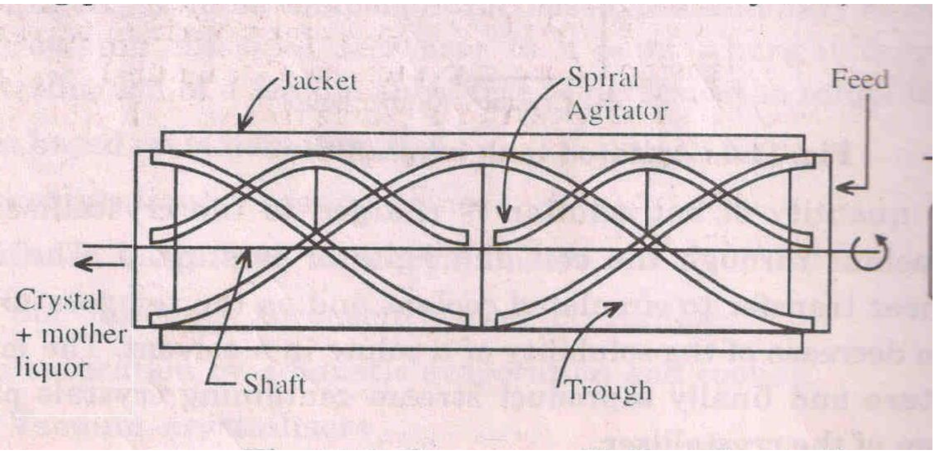
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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.

Q No.	Answer	Marking scheme
1 a	Attempt any 3	12
1A-a	**Salient features of two film theory** : 1) Resistance to transfer in each phase is regarded as lying in a thin film close to the interface. 2) The transfer in these films is by a steady state process of molecular diffusion. 3) The concentration gradient is assumed to be linear in these films and it is zero outside the films,i.e.,zero in the bulk fluid 4) The theory assumes that the turbulence in the bulk fluid vanishes at the interface of the films. 5) The film capacity is negligible,i.e.,the time taken for a concentration gradient to establish is small compared to the time of transfer.	1 mark each for any 4
1A-b	**Bubble cap tray**:	4

	 Bubble cap .	
1A-c	**Selection criteria for solvent selection in liquid-liquid extraction:** 1. **Selectivity:** 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. 2. **Recoverability:** 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. 3. **Distribution coefficient:** Higher values are desirable as less solvent will then be required for given extraction duty. 4. **Density:** The difference in densities of saturated liquid phases should be larger for physical separation. 5. **Insolubility of solvent:** 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. 6. **Chemical Stability:** The solvent should be stable chemically and inert towards other components and should not be corrosive. 7. **Cost:** The solvent should be cheap.	1 mark each for any 4

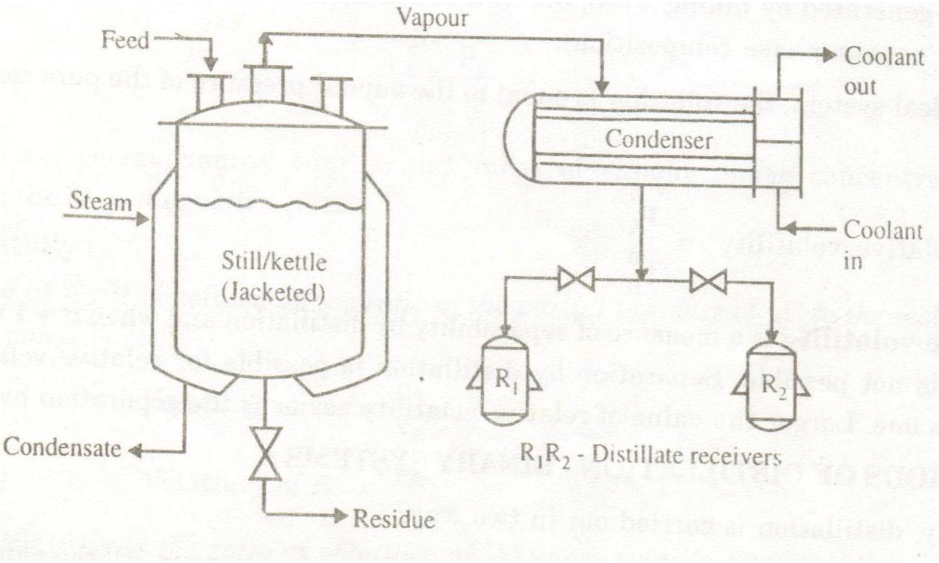
<table>
<tr><td></td><td>8. The solvent should be non toxic, non flammable.
9. Solvent should have low viscosity, freezing point, vapor pressure for ease in handling and storage.
10. Interfacial tension: It should be high for coalescence of emulsions to occur more readily, as the same is of greater importance than dispersion.</td><td></td></tr>
<tr><td>1A-d</td><td>Factors on which the rate of drying depends:
1) Gas Velocity: When the velocity of the gas or air is high the rate of drying will also be high.
2) Humidity of gas : Lesser the relative humidity, the more will be the rate of drying.
3) Area of drying surface: If the area of the wet surface exposed to the gas or air is more, the rate of drying will also be more.
4) Temperature: If the temperature of the gas is increased’ it’s relative humidity decreases (i.e gas becomes more unsaturated) and thus increase a driving force (i.e the concentration difference of moisture between the solid and gas) and so the rate of drying increases.</td><td>1
1
1
1</td></tr>
<tr><td>1B</td><td>Attempt any 1</td><td>6</td></tr>
<tr><td>1B-a</td><td>$\alpha = 2.5$
$Y = (\alpha x / 1 + (\alpha - 1) x$
Calculate x-y data
<table>
<tr><td>x</td><td>0</td><td>0.1</td><td>0.2</td><td>0.3</td><td>0.4</td><td>0.5</td><td>0.6</td><td>0.7</td><td>0.8</td><td>0.9</td><td>1</td></tr>
<tr><td>y</td><td>0</td><td>0.22</td><td>0.385</td><td>0.52</td><td>0.625</td><td>0.71</td><td>0.79</td><td>0.85</td><td>0.91</td><td>0.96</td><td>1</td></tr>
</table>

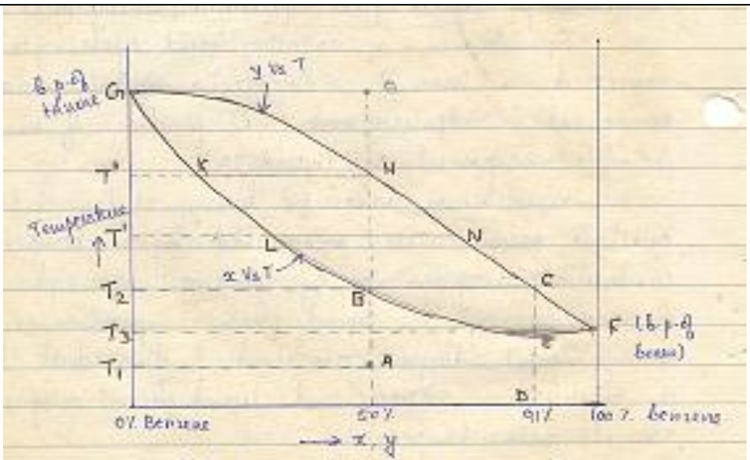
Plot equilibrium diagram with x on x axis and y on y-axis</td><td>1
3
2</td></tr>
</table>

		
1B-b	**Swenson-walker Crystallizer:**  i) It is the cooling type continuous jacketed trough crystallizer. ii) It is an example of scrapped surface crystallizer.	2

	iii) 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. iv) Feed is admitted at one end and mixture of crystals and mother liquor is removed from other end.	
	Construction: It consists of a long open rectangular trough with a semi cylindrical bottom that is u shaped trough,of width 0.6m and length 3-6m.□ The trough is jacketed externally for circulating the coolant during operation.□ A spiral agitator rotating at about 7 rpm is incorporated in the trough in such a way that it is as close to the bottom of the trough as possible.□ At one end of the crystallizer an inlet foe hot solution isprovided.an at the other end, an over flow gate for the crystals and mother liquor discharge is provided,· The function of spiral agitator include to scrap crystal, to lift and shower the crystal of uniform size, and to convey crystal from one end to the other end of equipment.	2
	Working: The hot concentrated solution is fed at one end of the open trough and flows slowly towards the other end of trough. Water is fed to the jacket in such a way that it flows in a counter current fashion with respect to the solution. The solution while flowing trough the trough is cooled by heat transfer to water. Once the solution becomes super saturated crystals starts forming and building. A spiral agitater keeps the crystal in suspension so that previously formed crystal grow instead of formation of new crystal. Ultimately the two phase mixture of crystal an liquor leaves the crystallizer through an overflow gate.	2
2	**Attempt any 4**	16

2-a	**Supersaturation:** It is the quantity of solute present in the solution in which crystals are growing compared with the quantity of the solute that is in equilibrium with the solution. **Different methods of obtaining super saturation** i) By cooling a concentrated, hot solution trough indirect heat exchange. ii) By evaporating a part of solvent/ by evaporating a solution. iii) By adiabatic evaporation and cooling. iv)By adding a new substance which reduces the solubility of the original solute, i.e. by salting. v)By chemical reaction with a third substance	1 3
2-b	**Working of fluidized bed dryer**: A fluidized bed system in addition to a fluidizing chamber also needs an air blower, a hot air generator, a feed conveyor, a cyclone separator and a product conveyor. In this drier, hot air is used to keep the wet feed in a fluidized state. In the drier the wet material is dried and cooled in the same bed. Wet feed material is admitted to the top of the bed through a hopper via a rotary valve and hot air is distributed at the bottom of the bed through a diffuser plate and dry product is taken out from the side or near the bottom. Heat and mass transfer coefficient are high because of the turbulence created in the bed. The material to be dried and hot air are in cross-flow with respect to the direction of flow of each other. The residence time can be controlled from seconds to hour. The moist air from the drier containing fines is admitted to a cyclone separator for the recovery of fines.	4
2-c	**Differential distillation** : In this distillation technique, a known quantity of a liquid mixture is charged into a jacketed kettle or still. The jacket is provided for heating the liquid mass in the still with the help of a heating media such as steam. the charge is boiled	2

	slowly, vapours formed are withdrawn and fed to a condenser where they are liquefied and collected in a receiver as a distillate. in the early stage of distillation, vapours leaving the still are richest in the more volatile component and as the distillation proceeds the liquid in the still becomes lean with respect to the more volatile component. The composition of the less volatile component thereby increases and hence the boiling point increases. The produce (distillate) from such units can be collected in several receivers, called cuts, to give products of various purities over the length of distillation period. the distillation is continued till the boiling point of liquid reaches a predetermined value and the content of the still is finally removed as residual liquid containing majority of the less volatile component.  	2
2-d	**Boiling point diagram**	2



(Boiling point diagram)

Consider the process of boiling a binary mixture consisting of benzene (mvc) and toluene. The composition of the mixture is plotted on x-axis in terms of mvc and temperature of the mixture is plotted on y-axis.

2

The mixture represented by point A is at a temperature of T1 and contains 50% benzene. When we heat the mixture it will boil at a temperature T2, vapours will contain more of mvc. The vapoursat C is in equilibrium with liquid at B and thus BC is known as the tie line.If we reheat the condensate obtained at this stage, it will boil at T3 and the vapours issuing will contain more of mvc,thus enrichment of benzene takes place .

In the process of boiling, the mixture boils over a temperature range, so the term used is bubble point.The liquid represented by any point on the lower curve is at its bubble point and the lower curve is called bubble point temperature curve.

When a mixture of vapours is cooled, at a point condensation starts. The first drop of liquid will have composition represented by point K.While cooling the vapour becomes richer in mvc than liquid. The condensation starts at any point on the upper curve. The upper curve is the dew point temperature curve.

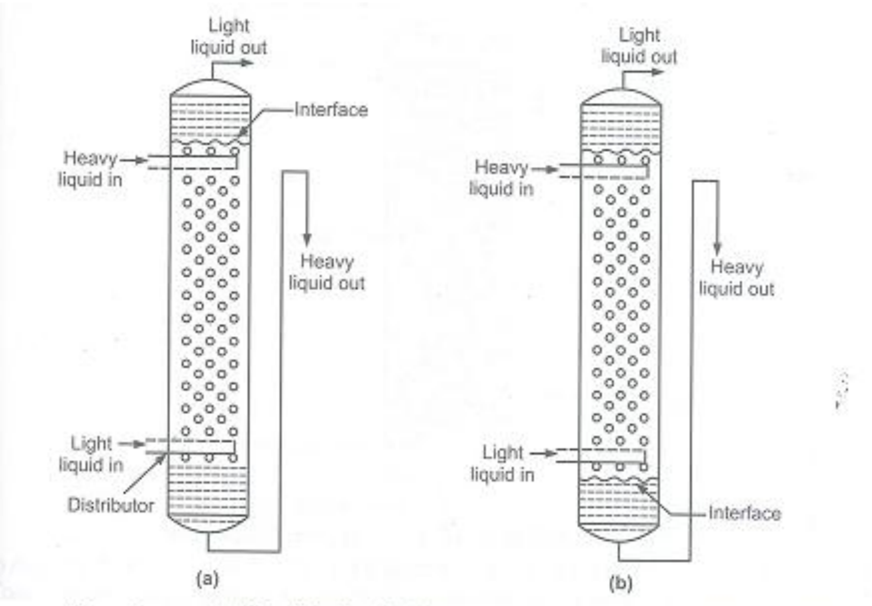
2-e	**Differentiate between distillation and extraction**	1 mark each for any 4

Distillation	Extraction
Constituents of liquid mixture are separated by using thermal energy	Constituents of liquid mixture are separated by using insoluble liquid solvent
It utilizes the difference in vapour pressure of the components to effect separation	It utilizes the difference in solubilities of the components to effect separation
Relative volatility is used as a measure of degree of separation	Selectivity is used as a measure of degree of separation
A new phase is created by addition of heat	A new insoluble liquid phase is created by addition of solvent to feed
Gives almost pure product	Doesn't give pure product
Requires thermal energy	Requires mechanical energy for mixing and separation
Needs heating and cooling provisions	Doesn't need heating and cooling provisions
Primary choice for separation	secondary choice for separation

3	**Attempt any 2**	16
3-a	Basis: 1kmol of feed.	
	X_F = mole fraction of hexane in the feed = 50/100=0.5	1
	Feed is 50 mole% vaporized	
	f= 50/100=0.5	1
	The operating line for flash distillation is	
	$Y=-((1-f)/f)X+XF/f$	1
	Slope= $-(1-f)/f = -(1-0.5)/0.5 = -1$	1

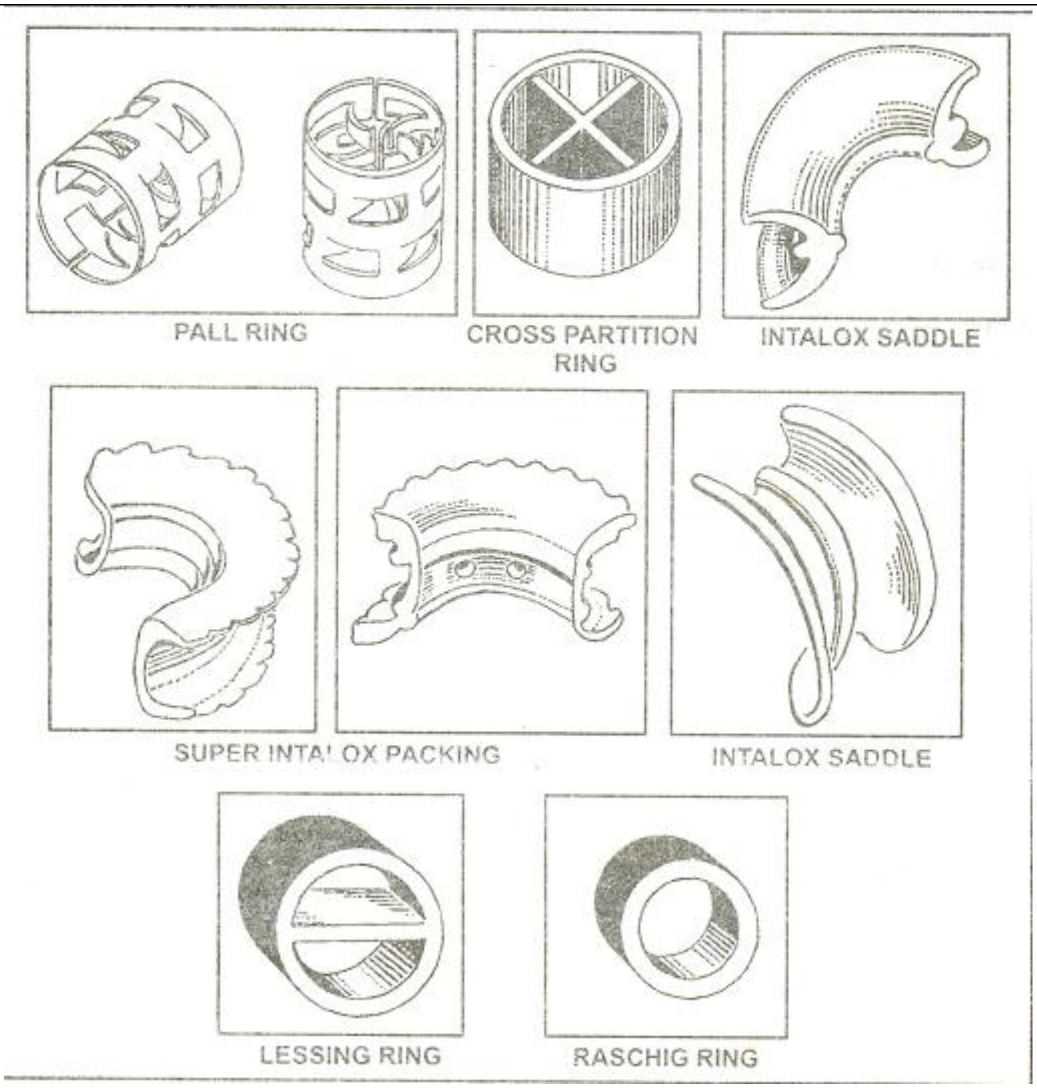
	The point of intersection of the operating line with the diagonal is (0.5,0.5).	
	Draw the equilibrium curve and draw the operating line with the slope to -1 passing through (0.5,0.5) on the diagonal. It intersects the equilibrium curve at	2
	P which gives us the equilibrium liquid and vapour compositions as **0.3** and **0.69** mole fraction hexane respectively.	2
3-b	Solution:	
	Basis: 100 kg feed	
	Weight of benzene in feed = 40 kg	
	Weight of toluene in feed = 60 kg	
	Mol fraction of benzene in feed (x_F) = (40/78) / [(40/78) + (60/92)] = 0.44	
	Mol fraction of benzene in distillate (x_D) = (96/78) / [(96/78) + (4/92)] = 0.966	
	Mol fraction of benzene in residue (x_w) = (5/78) / [(5/78) + (95/92)] = 0.058	2
	Relative volatility = 2.5	
	Generate x-y data	
	Draw equilibrium diagram	2
	q=1/3=0.33	
	Slope of feed line = -(q/1-q) = -0.5	
	Draw feed line through point(0.44,0.44) on diagonal with slope = -0.5 which will cut equilibrium curve at point P	
	Minimum reflux(Rm) = (0.966-0.515) / (0.515-0.3)	1
	= 2.1	
	R = 1.5 Rm	
	= 3.14	1
	Y intercept of rectifying section operating line is x_D/ R+1 = 0.232	
	Draw operating line for stripping section	1
	Construct triangles between equilibrium curve and operating lines and count number of completed triangles	

<table>
<tr><td></td><td>Number of theoretical stages (including reboiler) =10</td><td>1</td></tr>
<tr><td>3-c</td><td>Solution:
x- mol fraction of n-heptane in liquid
y- mol fraction of n-heptane in vapour
$x= (P-P_B^0) / (P_A^0- Pp_B^0)$ $y= P_A^0.x/ P$
P= 101.325 KPa $P_A^0 = 101.325$ $P_B^0= 44.396$
set 1
x = (101.325-44.396)/ (101.325-44.396)=1
y = 101.325*1/ 101.325 = 1
similarly calculate all x and y values
<table>
<tr><td>T</td><td>371.4</td><td>378</td><td>383</td><td>388</td><td>393</td><td>398.6</td></tr>
<tr><td>x</td><td>1</td><td>0.656</td><td>0.487</td><td>0.312</td><td>0.157</td><td>0</td></tr>
<tr><td>y</td><td>1</td><td>0.810</td><td>0.673</td><td>0.492</td><td>0.28</td><td>0</td></tr>
</table></td><td>1
1
1
5</td></tr>
<tr><td>4 A</td><td>Attempt any 3</td><td>12</td></tr>
<tr><td>4A-a</td><td>Spray column:
Spray towers consists of an empty tower provided with inlet and outlet connections at the top and bottom, for introducing and removing the heavy and light end phases. In these towers mixing and settling proceeds simultaneously, and there is a continuous transfer of material between phases, and composition of each phase changes as it flows through the tower. Either light or heavy phase may be dispersed, but generally the phase with high flow rate and the phase of high viscosity should be dispersed.
Spray towers are operated in two ways – either light phase or heavy phase may</td><td>2</td></tr>
</table>

	be dispersed. When light phase is to be dispersed, it is introduced through the nozzle from bottom, droplets rise through heavy phase and finally coalesce to form liquid- liquid interface at the top. In operation, where heavy phase is dispersed, it enters the tower from top, droplets fall through light phase and finally coalesces to form liquid- liquid interface at the bottom of the tower and then leaves the tower in the form of stream through bottom outlet. Light phase is introduced at bottom and leaves from top.  . Spray towers (a) for light liquid dispersed and (b) for heavy liquid dispersed	2
4A-b	**Fick's law** is the basic law of diffusion Fick's law 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. $J_A = -D_{AB} dC_A/dZ$ Where J_A- molar flux of A in z direction C_A – concentration of A dC_A/dZ – concentration gradient in z direction	2 2

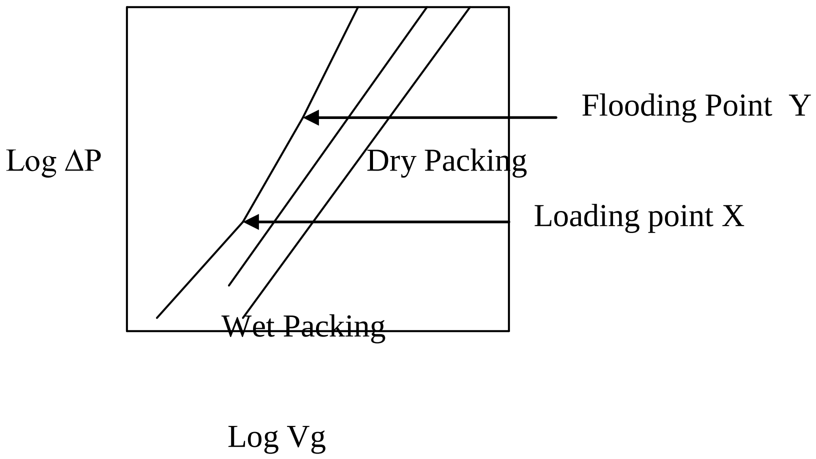
	D_{AB} – proportionality constant, diffusion coefficient Z – distance in the direction of diffusion	
4A-c	**Steam Distillation:** **Principle:** Steam distillation is adopted in cases where substance involved cannot withstand temp of distillation and decompose. Substance of this kind can be separated by reducing the partial pressure of the volatile component. This can be done by making use of inert vapour that decreases the temperature of distillation. The inert vapour used should be practically immiscible with components to be distilled. Steam is used for this purpose. In steam distillation, steam is directly admitted into the liquid in the still. The mixed vapour containing desired component is taken as overhead, condensed and desired component is separated from water phase by gravity while non volatile material remains behind in the still.	2
	Application: 1. For separating high boiling component from non volatile impurities. 2. For separating high boiling mixture into different fractions wherein the decomposition of material might occur if direct distillation were employed 3. Where vaporization temperature cannot be reached by heat	2
4A-d	**Selection criteria for solvent in gas absorption** : While selecting a particular solvent for absorption operation , the following properties of the solvent are considered. 1) Gas solubility : the solubility of solute gas in a solvent should be high . the solvent selected should have a high solubility for the solute to be absorbed 2) Volatility : As the gas leaving an absorption unit is generally saturated with the solvent, there will be a loss of the solvent with the gas leaving the unit	1 mark each for any 4

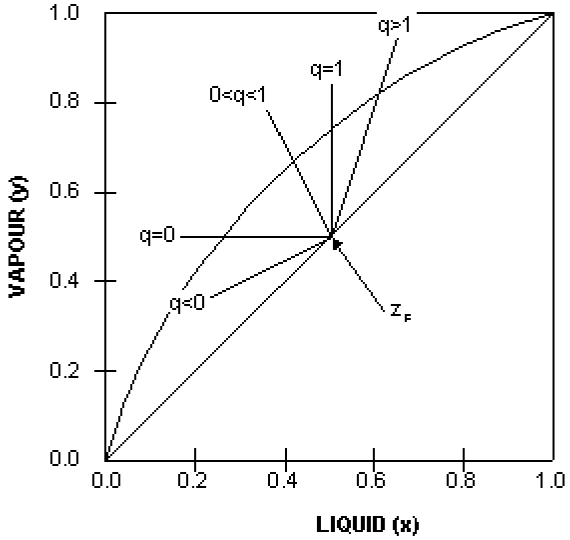
	operation, hence to minimize the solvent loss , the solvent should be less volatile. 3) Corrosive nature : the solvent should not be corrosive towards common materials of construction so that the construction material for an absorption equipment will not be too expensive. 4) Viscosity : the solvent should have a low viscosity for rapid absorption rates, low pumping cost and better heat transfer. The solvent should be non viscous. 5) Cost and availability : the solvent should be cheap and readily available 6) Miscellaneous : the solvent should be non-toxic, non-flammable, non-foaming, and chemically stable from a handling and storage point of view.	
4B	Attempt any 1	6
4B-a	**Types of packings**: In order to obtain the efficient gas liquid contact, many different types of packings are available ranging from simple to complex geometrical shapes but are generally classified as random packings and regular packings. If the packing are simply dumped into the tower during installation and fall in random fashion they are called **random packings.** The packings arranged in a particular pattern are called **stacked packings.** Most common random packings are : 1) Raschig rings. MOC-Ceramic, carbon and metal 2) Pall rings. MOC-Metal or plastic 3) Berl saddles. MOC-Plastic or ceramics 4) Intalox saddles. MOC-Plastic or ceramics 5) Super intalox saddles. MOC-Plastic or ceramics	2 marks for any 4 types 2 marks for MOC

		1 mark each for any 2
4.B b	Initial moisture content $X_1 = 0.3/(1-0.3) = 0.428$ Final moisture content $X_2 = 0.16/(1-0.16) = 0.19$ $R_C = 0.7*10^{-3}* 3600 = 2.52$ kg/m^2 hr $A/W^1 = 0.3$ or $W^1/ A = 33.33$kh/m^2 $t = W^1/ AR_c\{ (X_1-X_2)$ $t = 33.33/2.52(0.428-0.19)$	 2 2 2

	= **3.15 hr**	
5	Attempt any4	16
5-a	Azeotrope is a liquid mixture with an equilibrium vapour of the same composition as the liquid. The dew point and bubble point are identical at azeotropic composition and the mixture vaporizes at a single temperature, so azeotropes are called constant boiling mixtures. when an azeotrope is boiled , the vapour produced will have the same composition as the liquid from which it is produced .boiling of an ordinary solution takes place from the bubble point to the dew point , whereas the boiling point of an azeotropes remains constant till the entire liquid is vaporized. **Minimum boiling azeotrope**: Minimum boiling azeotrope will boil at a temperature lower than the boiling points of pure components. **Maximum boiling azeotrope**: Maximum boiling azeotrope will boil at a temperature higher than the boiling points of pure components.	2 1 1
5-b	**Rayleigh equation:** Let F be moles of liquid mixture containing x_F mol fraction of A, D kmoles of distillate and W kmoles of residual liquid in still which are obtained at the end of operation. Let y_D and x_W be the mol fr of A in distillate and bottom residual liquid. Let L be kmoles of liquid in the still at any time during the course of distillation and let x be mol fr of A in liquid.Let very small amount dD kmol of distillate of composition y in equilibrium with the liquid is vaporized. Then composition and quantity of liquid decreases to (x-dx) and L to (L-dL) respectively. Overall material balance is L=L-dL+dD Or dL= dD	2

	Material balance for component A is $Lx=(L-dL)(x-dx)+ydD$ $Lx= Lx-Ldx-xdL+dLdx+ydD$ $dLdx=0$ $0= -Ldx-xdL+ydL$ But $dD=dL$ i.e. $0=-Ldx-xdL+ydL$ $Ldx=(y-x)dL$ $dL/L=dx/(y-x)$ Integrating the equation between the limits $L=F$, $x=x_F$, $L=W$ $x=x_W$ $\int_{W}^{F} dL/L= \int_{xW}^{xF} dx/(y-x)$ $Ln(F/W) = \int_{x_W}^{x_F} dx/(y-x)$ **This is Rayleigh's equation**	2
5-c	**Hydrodynamics / pressure drop characteristics in packed column:** In a packed column there are two flows flowing in counter current direction. Liquid fed at the top of coloumn flows down the column through the void spaces in the packings, the same time gas mixture is forced up through the void spaces by using a blower or a compressor. To maintain flow of gas ,pressure at the top must be less than that at the bottom. In packed column as same channels are available for liquid down flow & gas up flow, the gas pressure drop is a function of both phase flow rates & is important in design of packed column. The variation of pressure drop with gas velocity is plotted on log-log graph as shown in fig.	2

	 In case of dry packing, the relationship between pr.drop and gas velocity is represented by a straight line indicating that pressure drop is proportional to $G^{1.8-2}$. For wet packing, the relationship is indicated by straight line, but for a given velocity, pressure drop will be more than that for dry packing. With the liquid flow down the tower at low and moderate gas velocities, pr.drop is proportional to 1.8th power of gas velocity. Up to point X the amount of liquid held up in packing is constant. At point X the gas flow begins to impede the down flow of liquid and local accumulation of liquid appears here and there in packings. As the gas velocity increases further liquid hold up progressively increases due to which free area for gas flow becomes smaller and pressure drop rises much more quickly. At gas flow rates beyond Y, pr.drop rises very steeply. At point Y, entrainment of liquid by gas leaving the top of tower increases and tower is then said to be flooded. The gas velocity corresponding to the flooding conditions is called as flooding velocity.	2
5-d		2

	 **Feed line** q = 0 (saturated vapour) q = 1 (saturated liquid) 0 < q < 1 (mix of liquid and vapour) q > 1 (subcooled liquid) q < 0 (superheated vapour)	2
5-e	**HETP(Height Equivalent to a Theoretical Plate):** It is the height of a section of packing that will give the same separation as that achieved with one theoretical plate Height of packed column = NTU*HTU Where, NTU = Number of transfer units HTU = Height of transfer units	2 2
6	Attempt any 2	16
6-a	**Time of drying under constant drying conditions:** Consider that the wet solids are to be dried by passing the hot air over them under constant drying conditions. The time of drying required to dry the material from initial moisture to the final moisture content of solids, is the sum	

of the time required during the falling rate period.

Constant rate period :

Let X1 be the initial moisture content of the wet solids and X_2 be the final moisture content of the wet solids during the constant rate period. Let X_C be the critical moisture content of the wet solids. 1

The rate of drying is given by

$$R = -\frac{W'}{A} \times \frac{dX}{dt} \qquad \text{-----------------(1)}$$

$$R = R_C = \text{rate during constant rate period}$$

$$R_C = -\frac{W'}{A} \times \frac{dX}{dt} \qquad \text{----------------(2)}$$ 1

Where

W' = mass of dry solids in kg
A = area of drying surface in m^2
R_C = rate in $kg/(m^2.h)$
t = time in hours (h)

Rearranging Equation (2), we get,Type equation here.

$$dt = \frac{W'}{A.RC}\ dX \qquad \text{----------------(3)}$$

Integrating Equation (3) between the limits :

$t = 0, \quad X = X_1$
and $t = t, \quad X = X_2,$ we get 1

$$\int_0^t dt = -\frac{W'}{A.RC} \int_{X1}^{X2} dX \qquad \text{----------------(4)}$$

$$t = -\frac{W'}{A.RC}\ [X_2 - X_1] \qquad \text{----------------(5)}$$

$$t = \frac{W'}{A.R_C}[X_1 - X_2] \qquad \text{----------------(6)}$$

equation (6) gives the time required for drying the material from X_1 to X_2 in the constant rate period.

If the material is to be dried to the moisture content ofX_C, then the time required during the entire constant rate period is given by

$$t_C = \frac{W'}{A.R_C}[X_1 - X_C] \qquad \text{----------------(7)}$$ 1

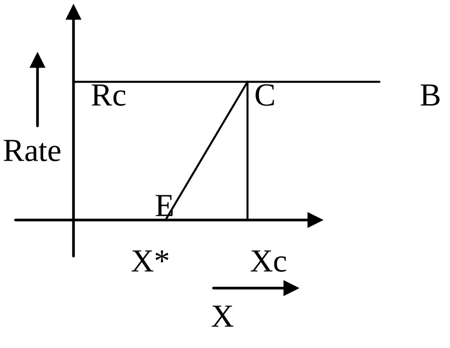
Falling rate period :

During this period the rate of drying is proportional to the free moisture content.

$$-\frac{W'}{A} \times \frac{dX}{dt} = m[X - X^*] \qquad \text{----------------(8)}$$ 1

Where X* is the equilibrium moisture content and X is the moisture content of wet solids less than critical moisture content.

Let X_1 be the initial moisture and X_2 be the final moisture content such that $X_1, X_2 < X_C$.



Assume that the entire falling rate period is represented by a straigh line CE, then

$$m = \frac{R_C}{[X_C - X^*]} \qquad \text{----------------(9)}$$ 1

m = slope of line CE

Equation (1) then becomes

$$-\frac{W'}{A} \times \frac{dX}{dt} = \frac{RC}{[XC-X^*]} \; [X - X^*] \qquad \text{----------------(10)}$$

$$-\frac{dX}{[X-X^*]} = \frac{RC\,A}{[XC-X^*]W'}\,dt \qquad \text{----------------(11)}$$

Integrating Equation (11) between the limits :

$X = X_1$

$X = X_2$ $[X_{1,}$ $X_2 < X_C]$, we get

$$\int_{X1}^{X2} \frac{dX}{[X-X^*]} = \frac{RC\,A}{[XC-X^*]W'} \int_0^t t \qquad \text{----------------(12)}$$

$$t = \frac{[XC-X^*]\,W'}{RC\,A} \ln \frac{X1-X^*}{X2-X^*} \qquad \text{----------------(13)}$$ 1

Equation (13) gives the time of dying during the falling rate period to dry the material from X_1 to X_2.

If the material is to be dried from the critical moisture content X_C to the final moisture content X_2 ($X_2 < X_C$), then the time required for drying during the entire falling rate period is given by t_f as :

1

$$t_f = \frac{[XC-X^*]\,W'}{RC\,A} \ln \frac{XC-X^*}{X2-X^*} \qquad \text{----------------(14)}$$

[As X_1 becomes X_C]

t_f = drying time during entire falling rate period.

Total time of drying = $t_C + t_f$

	$t = \frac{W'}{A.R_C}\left[(X_1 - X_C) + (X_C - X^*)\right] \ln \frac{X_C - X^*}{X_2 - X^*}$ --------(15)	
6-b	Area = $0.01 m^2$	
	Weight of dry saw dust(W') = 0.15 kg	
	Set 1	
	Initial moisture content(X_1) = 100/150 = **0.667**	1
	Final moisture content(X_2) = 80/150 **= 0.533**	1
	t= 0.5 hr	
	$t = W'(X_1 - X_2) / AR$	1
	or $R = W'(X_1 - X_2) / A.t$	
	= 0.15(0.667-0.533) / 0.01. 0.5	
	= **4.02 Kg/m^{2}hr**	1
	Set 2	
	Initial moisture content(X_1) = 100/150 = **0.667**	1
	Final moisture content(X_2) = 65/150 **= 0.433**	1
	t= 0.75 hr	
	$t = W'(X_1 - X_2) / AR$	1
	or $R = W'(X_1 - X_2) / A.t$	
	= 0.15(0.667-0.433) / 0.01. 0.75	
	= **4.68 Kg/m^{2}hr**	1
6-c	Solubility of $MgSO_4$ is 64.2 parts per 100 parts water at 353 K	
	Basis: 100 kg of feed solution.	
	Water in feed = 1000(1-0.391) = 609	
	Water evaporated= 0.1(609) = 60.9	2
	Let 'C' be the yield of crystals.	

	M1 = Molecular weight of $MgSO_4$ = 120 M2 = Molecular weight of $MgSO_4\,7H_2O$ =246 XF'=64.2/164.2 = 0.391 Material balance of water : Water in feed = Water evaporated + Water of crystallization in crystals + Water in mother liquor.	
	1000(1-0.391) = 60.9+C.(126/246) + L'	2
	L'= 609 – 60.9 + 0.5122 C Material balance of solute:	
	Solute in feed = Solute in crystals produced +Solute in mother liquor	2
	0.391x100 = c(120/246)+[609 – 60.9 + 0.5122 C]X' Assume the value of X since the data is not given in the paper	
	Let X=0.408	2
	C=**599.7 kg**.	