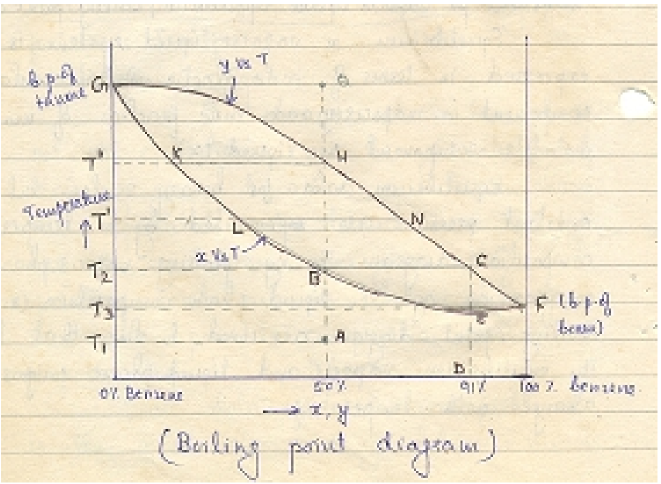
SUMMER-15 EXAMINATION

Model Answer

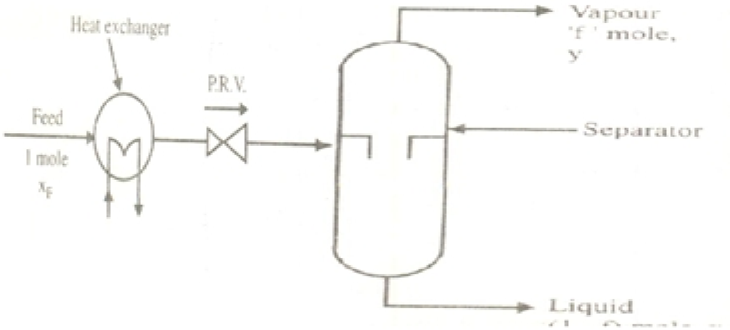
Subject code :(17648)

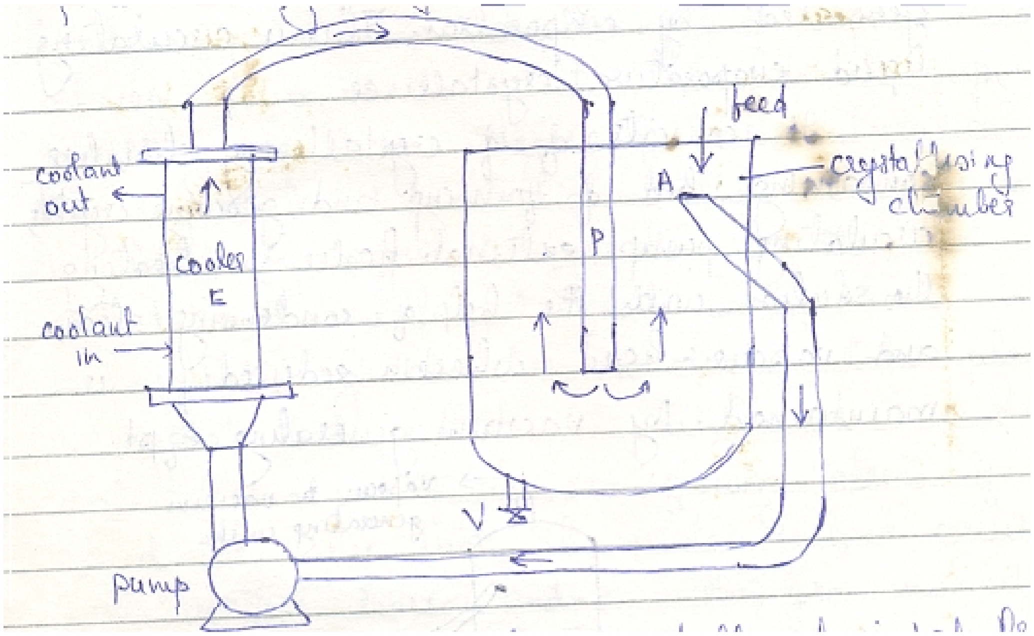
Important Instructions to examiners:

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.

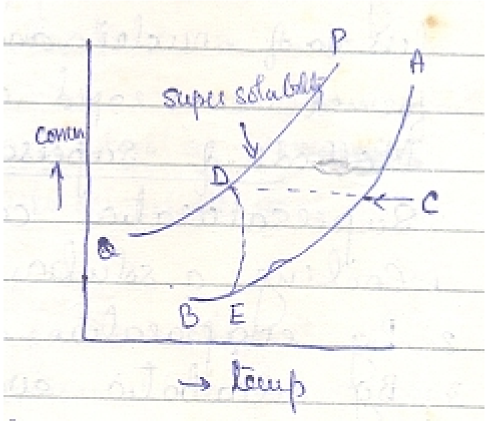
Q No.	Answer	marks	Total marks
1a-i	**Fick's law** is the basic law of diffusion		4
	Fick's law states that the flux of a diffusing component A in z direction in a binary mixture of A and B is proportional to the molar concentration gradient.	2	
	$J_A = -D_{AB} dC_A/dZ$ Where J_A- molar flux of A in z direction C_A – concentration of A dC_A/dZ – concentration gradient in z direction D_{AB} – proportionality constant, diffusion coefficient Z – distance in the direction of diffusion	2	
1a-ii	**Boiling point diagram:** 		4
	Equilibrium data for binary system at constant pressure are presented in temperature composition diagram or by plotting vapour phase composition against liquid phase composition. Boiling point diagram are used to show that how the equilibrium vapour and liquid phase composition changes with	2	

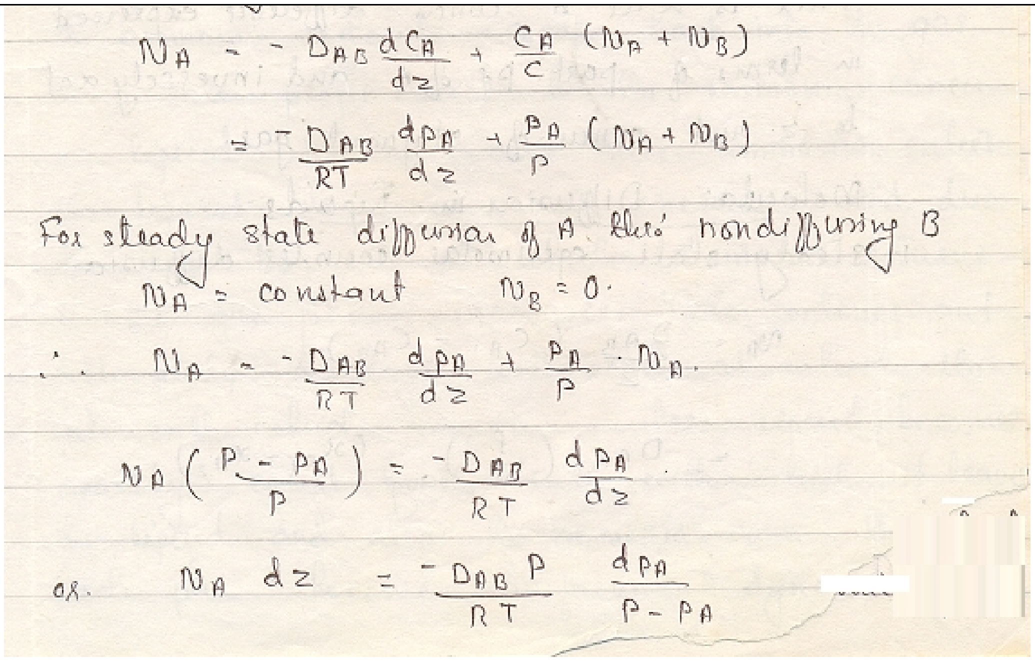
	temperature .In the diagram the composition of benzene – toluene mixture is plotted on X axis in terms of more volatile component and temperature of the mixture is plotted onY axis. The upper curve is saturated vapour line and lower curve is saturated liquid line. **Effect of total pressure on boiling point diagram:** As total pressure of the system is increased, the spread between the bubble point curve and the dew point curve decreases and separability by distillation becomes less.	2	
1a-iii	**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. **8.** The solvent should be non toxic, non flammable. **9.** Solvent should have low viscosity, freezing point, vapor pressure for	1 mark each for any 4	4

	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.		
1a-iv	**Factors on which the rate of drying depends:**		4
	1) **Gas Velocity**: When the velocity of the gas or air is high the rate of drying will also be high.	1	
	2) **Humidity of gas** : Lesser the relative humidity, the more will be the rate of drying.	1	
	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.	1	
	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.	1	
1b-i	**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  		6
	Consider one mole of liquid mixture having x_f mole fraction , f moles of feed that is vapourized and of composition y. Then (1-f) will be the moles of	3	

	residual liquid obtained. Let x be the mole fraction of more volatile component in liquid. Material balance for more volatile component is $x_F = fy+(1-f)x$ OR $y= -(1-f)x/f+(x_f/f)$ The above equation is operating line for flash distillation with slope = -(1-f)/f and y- intercept = x_F/f The point of intersection of operating line and diagonal (x=y) is (x_F ,x_F)	3	
1b-ii	**Oslo Cooler crystallizer** **Diagram** 	3	6

	Construction: In this crystallizer, super saturation is generated by indirect cooling. It consists of crystallizing chamber, circulating pump and external cooler for cooling the solution. **Working:** Feed solution to be crystallized is fed from top. Mother liquor from crystallizing chamber is withdrawn near feed point A with the help of circulating pump, and it is then admitted to the cooler E where super saturation is achieved by cooling. The super saturated solution from cooler is finally fed back to the bottom of crystallizing chamber through central pipe P. Nucleation takes place in the bed of crystals in crystallizing chamber. The nuclei formed circulate with mother liquor and once they grow sufficiently large, they will be retained in the fluidized bed. Once the crystals grow to required size, they are removed as product from bottom of crystallizing chamber through valve V as these can not be retained in the fluidized bed by circulation velocity.	3	
2-a	**Mier's supersaturation theory:** 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 maximium 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	4	4

	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. 		
2-b	**(i)Bound moisture:** It is the moisture in the substance which exerts a vapour pressure less than that of pure liquid at the given temperature. **(ii) Free moisture:** It is the moisture contained by substance in excess of equilibrium moisture content. It is the moisture content of the material that can be removed by drying. **(iii) Critical moisture:** The moisture content of material at which constant rate period ends and falling rate period starts is called critical moisture content. **(iv)Humidity:** It is the ratio of mass of water vapour to the mass of dry air present in air- water vapour mixture.	1 1 1 1	4
2-c	**Molar flux for diffusion of a gas A through stagnant gas B:**		



$$N_A = -D_{AB}\frac{dC_A}{dz} + \frac{C_A}{C}(N_A + N_B)$$

$$= -\frac{D_{AB}}{RT}\frac{dp_A}{dz} + \frac{p_A}{P}(N_A + N_B)$$

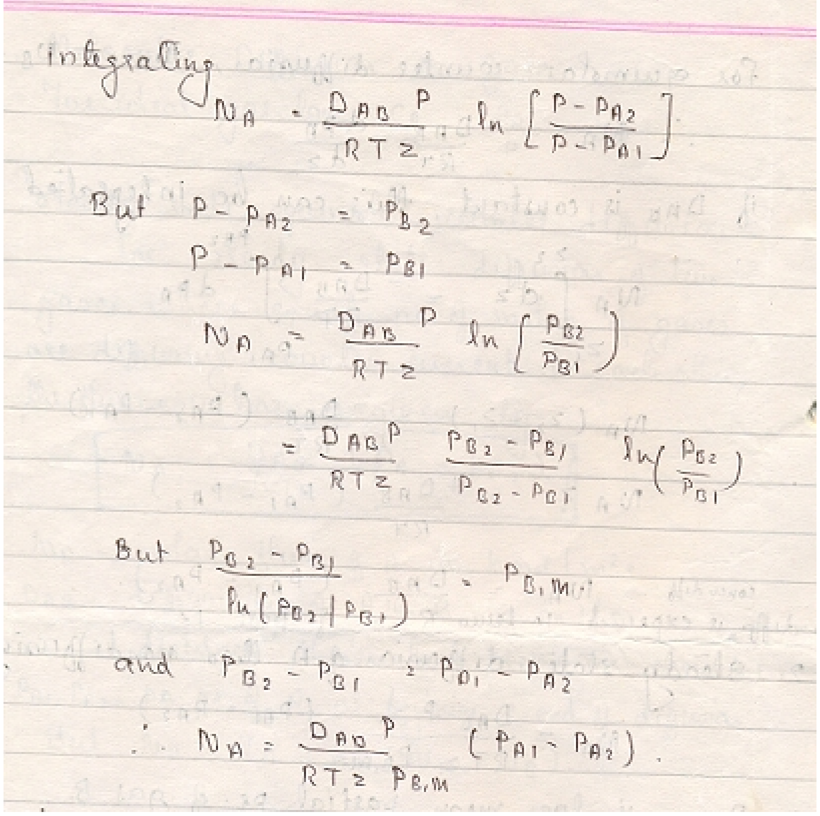
For steady state diffusion of A thro' nondiffusing B

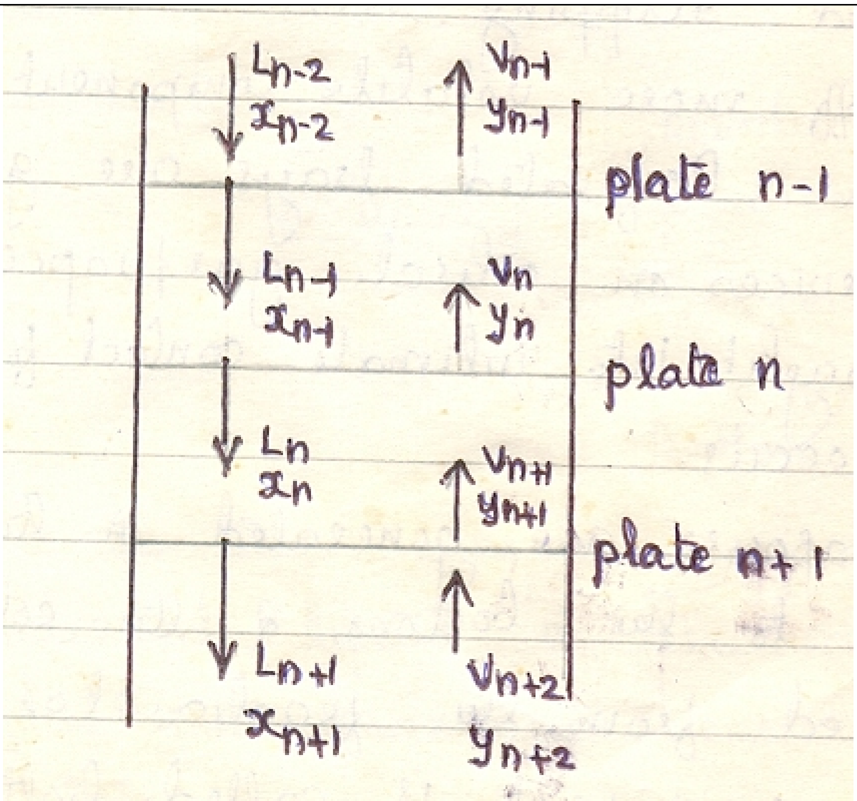
N_A = constant $N_B = 0$.

$$\therefore \quad N_A = -\frac{D_{AB}}{RT}\frac{dp_A}{dz} + \frac{p_A}{P}\cdot N_A.$$

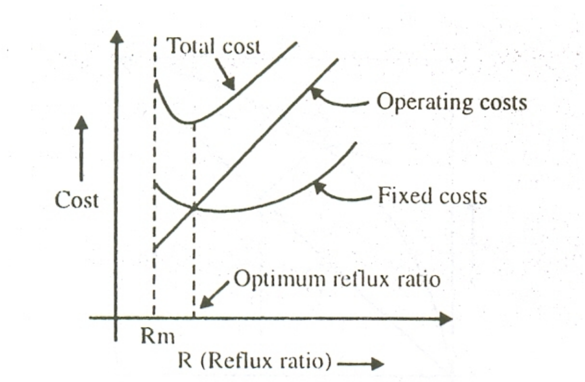
$$N_A\left(\frac{P - p_A}{P}\right) = -\frac{D_{AB}}{RT}\frac{dp_A}{dz}$$

or $$N_A\,dz = -\frac{D_{AB}P}{RT}\frac{dp_A}{P - p_A}$$

	 Integrating $N_A = \frac{D_{AB} P}{RTz} \ln\left[\frac{P - p_{A2}}{P - p_{A1}}\right]$ But $P - p_{A2} = p_{B2}$ $P - p_{A1} = p_{B1}$ $N_A = \frac{D_{AB} P}{RTz} \ln\left(\frac{p_{B2}}{p_{B1}}\right)$ $= \frac{D_{AB} P}{RTz} \frac{p_{B2} - p_{B1}}{p_{B2} - p_{B1}} \ln\left(\frac{p_{B2}}{p_{B1}}\right)$ But $\frac{p_{B2} - p_{B1}}{\ln(p_{B2}/p_{B1})} = p_{B,M}$ and $p_{B2} - p_{B1} = p_{A1} - p_{A2}$ $\therefore N_A = \frac{D_{AB} P}{RTz\, p_{B,M}} (p_{A1} - p_{A2})$.		
2-d	**Rectification on ideal plate:**		4

	 The plates are numbered serially from top to bottom. On every plate two different fluid streams not at equilibrium are brought into intimate contact, mass transfer takes place, phases are separated, and finally two fluid streams leave the plate in equilibrium with each other. When vapour from plate n+1 is brought into intimate contact on plate n with liquid from plate n-1, their composition change to attain equilibrium values. During the interchange process, some of more volatile component is vaporized from liquid L_{n-1}, decreasing the liquid concentration from x_{n-1} to x_n and some of the less volatile component is condensed from the vapour V_{n+1}, increasing the vapour concentration from y_{n+1} to y_n. In the column, the heat to vaporize more volatile component from liquid is supplied by the heat released in the condensation of less volatile component from vapour. The more volatile		

	component is transferred to the vapour rising up from the liquid running down the column , while the less volatile component is transferred to the liquid running down from the vapour rising up the column. The temperature decreases along the column height.		
2-e	**Situations where liquid- liquid extraction is preferred:** 1. Whenever very large amounts of latent heats are required 2. Whenever we are dealing with substances which are heat sensitive 3. Whenever we are dealing with liquid mixture forming azeotrope or close boiling mixture. **Selectivity :** The ratio of concentration ratio of solute to feed solvent in extract phase to that in raffinate phase. Selectivity should be high. **Significance of selectivity:** It is a measure of separation by extraction. When selectivity = 1, separation is not possible. Selectivity should be greater than 1.	1 mark each for any 2 1 1	4
3-a	**Reflux ratio R = L/D** $= \frac{\text{Amount of liquid fed back to coloumn}}{\text{Amount of liquid taken out as distillate}}$ The equation for operating line of rectifying section is given as $Y_n = \frac{Ln}{Ln+D} \quad x_{n+1} \quad + \quad \frac{XD}{Ln+1}$ $= \frac{Ln}{Ln/D+D} \quad x_{n+1} \quad + \quad \frac{XD}{Ln/D+1}$ $Y_n = \frac{R}{R+1} \quad x_{n+1} + \frac{XD}{R+1}$ No. of plates in a coloumn depends on value of R. If D = 0 where no product is taken out of coloumn and all of it is fed back to the coloumn, coloumn is said to work on total reflux R = 1. In this case the slope of operating line is equal to 1 and operating line coinsides with diagonal. No. of plates required are minimum with maximum purity.	1 1 2 1	8

	As you go on increasing feed value of D the operating line moves towards the equillibrium curve along the feed line and no. of stages go on increasing ultimately q-line and operating line meet each other on equillibrium curve . infinite no. of plates are required for his value of R. This represents minimum reflux ratio.	1	
	The coloumn is neither run at total reflux nor minimum reflux. It is run at optimum reflux ratio.The optimum reflux ratio is defined as reflux ratio at which total cost of operation (sum of fixed charges and operating charges) is minimum.The optimum reflux ratio is usually lines in the range of 1.1 to 1.5 times the minimum reflux ratio.	2	
			
3-b	The 'q' is a measure of the thermal condition of the feed and is dfined as the number of moles of saturated liquid resulting in the stripping section for each mole of feed introducd. Thus for a feed we get , $L' = L + qf$ $V = V' + (1-q)F$ **Derivation of q-line :** The liquid flow in the stripping section is		8

$$L' = L + qf$$

$$\therefore \quad L' - L = qf \qquad \text{-----------------} \ (1)$$ 2

Similarly, the vapour flow in the rectifying section is

$$V = V' + (1 - q) F \qquad \text{-----------------} \ (2)$$

$$\therefore \quad V - V' = (1 - q) F \qquad \text{-----------------} \ (3)$$

Overall material balance in the upper section of coloumn :

$$V = L + D \qquad \text{-----------------} \ (4)$$

Material balance of A in the upper section :

$$V_y = Lx + D x_D \qquad \text{-----------------} \ (5)$$

Overall material balance in the lower section :

$$V' = L' - W \qquad \text{-----------------} \ (6)$$

Material balance of A in the lower section :

$$V'y = L'x - W x_w \qquad \text{-----------------} \ (7)$$ 2

Subtracting Equation (7) from Equation (5)

$$y (V - V') = x (L - L') + D x_D + W x_w \quad \text{---------------} \ (8)$$

Overall material balance of A over the coloum as a whole :

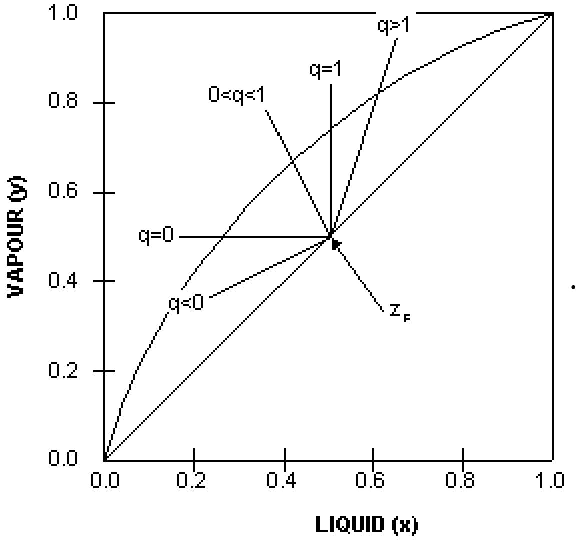
$$x_f . F = D x_D + W x_w \qquad \text{-----------------} \ (9)$$

$\therefore$ Equation (8) becomes

$$y (V - V') = x (L - L') + x_F . F \qquad \text{-----------------} \ (10)$$

Substituting the values of V - V' and L' – L from Equation (3) and (1) into Equation (10) gives

$$y (1 - q) F = x(-qF) + x_F . F$$

	$\therefore\ y = \frac{-q}{1-q}x + \frac{-XF}{(1-q)}$ ----------------- (11) Equation (11) is known as the **feed line or q-line** equation  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 2	
3-c	Basis : 50,000 kg/hr of feed wt% of Benzene = 30% ∴ wt of Benzene = 50000 × 0.3 = 15000 kg	1	8

	wt of Toulene = 35000 kg x_D on wt basis = 95% x_W on wt basis = 5% x_F on wt basis = 30% ∴ D = $\frac{F(x_{f-}x_{w})}{(x_D - x_w)}$ = $\frac{50000(0.3-0.05)}{(0.95-0.05)}$ = $\frac{50000(0.25)}{(0.9)}$ = 13888.88 kg ∴ wt of Benzene = 135888.88 × 0.95 = 13194.44kg wt of Toluene = 694.44 kg	1	

	F	D	R
Benzene	15000	13194.44	1805.56
Toulene	35000	694.44	34305.56

Moles of Benzene in feed = $\frac{15000}{78}$ = 192.30

Moles of Toluene in feed = $\frac{35000}{92}$ = 380.43

Total Moles = 572.73

	$x_F = \frac{192.30}{572.73}$ $= 0.33$ Moles of Benzene in distillate $= \frac{13194.44}{78} = 169.15$ Moles of Toulene in distillate $= \frac{694.44}{92} = 7.548$ Total moles in distillate $= 176.69$	1	
	$X_D = \frac{169.15}{176.69}$ $= 0.957$ Moles of Benzene in Residue $= \frac{1805.56}{78} = 23.148$ Moles of Toulene in Residue $= \frac{34305.56}{92} = 372.88$ Total moles in residue $= 396.028$	1	
	$X_w = \frac{23.148}{396.028}$	1	

$$= 0.058$$ 1

$$\alpha = 2.6$$

1

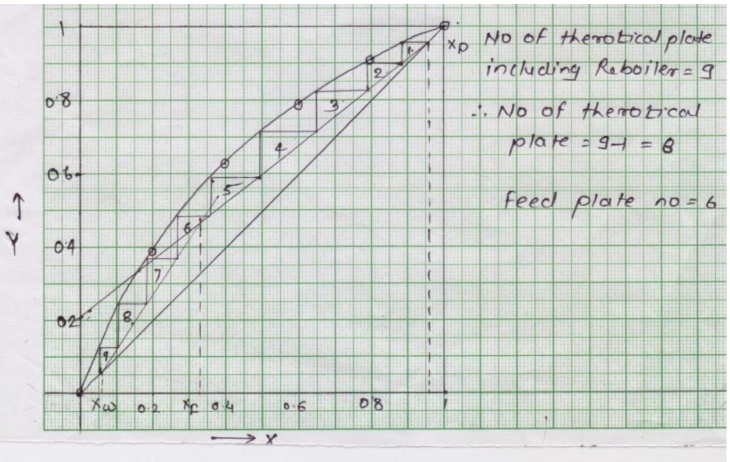
x	0	0.2	0.4	0.6	0.8	1
y	0	0.39	0.634	0.79	0.91	1

$$\text{Intercept} = \frac{x_D}{R+1}$$

$$= \frac{0.95}{3.5+1}$$

$$= 0.21$$ 1

No. of plates = 8



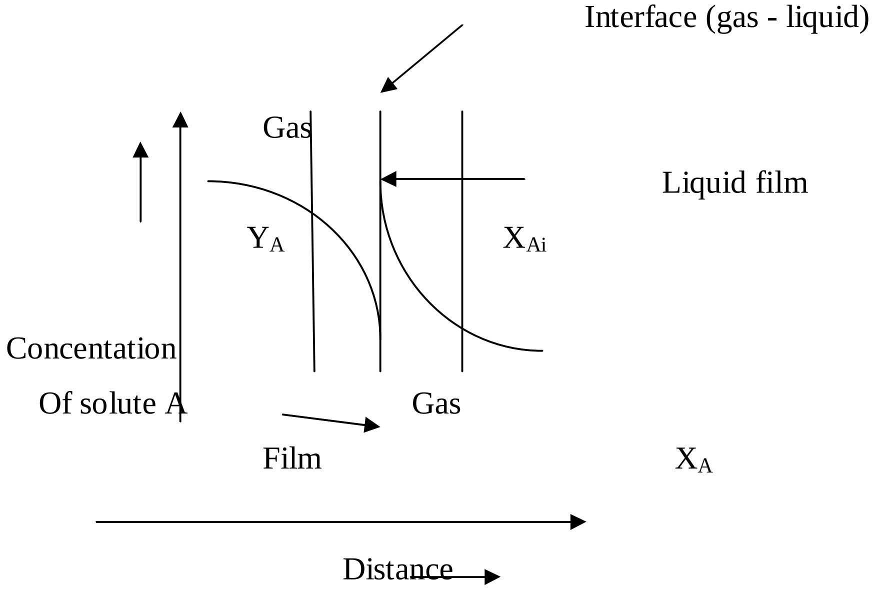
No of therotical plate including Reboiler = 9

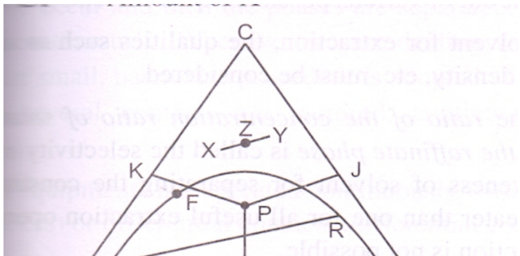
∴ No of therotical plate = 9-1 = 8

Feed plate no = 6

4a-i The addition of a new solvent to a binary liquid mixture yields different types 4

	of mixtures or systems.		
	I. The solvent may be completely immiscible with the feed solvent. This is the ideal case.	1	
	II. The solvent may be partially miscible with the feed solvent, forming one pair of partially miscible liquid. If A is the feed solvent, C is the solute and B is the extracting solvent, then C dissolves in A and B completely while A and B dissolve only to a limited extent in each other. This is the most common type of system.	1	
	III. A homogeneous solution may be formed, yhen the solvent selected is not suitable and should be rejected.	1	
	IV. The solvent may lead to the formation of two or three partially miscible liquids. A and C are completely soluble, while A and B, and B and C dissolve only to a limited extent in each other. It is observed ocassionally and not desired.	1	
4a-ii	**Whitman's two film theory:**		4
	a)Resistance to transfer in each phase is regarded as lying in a thin film close to the interface (i.e.,in two fictitious films one on each side close to the interface).	2	
	a) The transfer in these films is by a steady state process of molecular diffusion.		
	b) The concentration gradient is assume to be linear in this films & it is zero outside the films,i.e.,zero in the bulk fluid.		
	c) The theory assumes that the turbulence in the bulk fluid vanishes at the interface of the films.		
	d) The film capacity is negligble i.e.,the time taken for a concentration gradient to establish is small compared to the time of transfer.		

	 $\frac{1}{K_x} = \frac{1}{mK_y} + \frac{1}{K_x}$	2	
4a-iii	**Triangular diagram:** Consider a system consisting of C(Acetone), A(water), and B(methyl isobutyl ketone) at 25°C wherein aceton is the diluent and methyl isobutyl ketone is the solvent for extracting the solute. In this system , the solute C is competely miscible with the two solvents A and B and the two solvents A – b are partially miscible with each other . Apex C represents 100% acetone and apexes A and B represents 100% water and 100% methyl isobutyl ketone respectively. Along line BC , concentration of A is zero and the same is true for B and C along AC and AB. The ternary system represented by point P consists of three componentsC, Aand B in the ratio of perpendiculars PL, PJ and PK respectively. The distances AD and BE represent the solubility of solvent B in A and that of A in B, respectively. Every mixture of MIK and water of	3	4

	composition lying between points D and E forms two liquid layers, and for calculating mass ratio of these two layers , center of gravity principle is applicable. When acetone is added to two phase mixture of MIK and water , acetone gets distributed between the phases , and compositions of phases follow the raffinate phase and extract phase solubility curves. The curved line ERF indicates compsition of saturated MIK layer and the curved line DQF indicates the composition of saturated water layer. The area under the binodal solubility curve represented by the curved line DQFRE represents a two phase region that will split up into two layers in equilibrium with each other. Equilibrium composition of two phases lie on this curve. These two layers have composition represented by points Q and R and QR is a tie line. The line joining equilibrium compositions of the two phases is called the Tie – line. The point F on the binodal solubility curve represents a single phase which does not split into two phases and is known as a plait point. 	1	
4a-iv	$V'[Y_1 - Y_2] = L'[X_1 - X_2]$		4

X_1 = NH_3 component at bottom of tower
X_2 = NH_3 component at top (in solvent) 2
Y_1 = NH_3 component in inlet gas to tower
Y_2 = NH_3 component at outlet gas from tower

L' = Mass flow rate of free solvent in kg/hr
V'= Mass flow rate of free gas or air in kg/hr

150 [0.000957 – 0.000568] = L'[0.0005260 – 0.0000135] 1

L' = 113.85kg/h 1

4b-i 6

	Absorption	Adsorption
1	Assimilation of molecular species throughout the bulk of the solid or liquid is termed as absorption.	Accumulation of the molecular species at the surface rather than in the bulk of the solid or liquid is termed as adsorption.
2	It is a bulk phenomenon	It is a surface phenomenon.
3	Endothermic process	Exothermic process
4	It is not affected by temperature	It is favoured by low temperature

4

Criteria for selecting packing

1. Maximize the specific surface area - This maximizes vapour-liquid contact area, and, therefore, efficiency. 02
2. Spread the surface area uniformly - This improves vapour-liquid contact, and, therefore, efficiency.
3. Maximize the void space per unit column volume - This minimizes

	resistance to gas up flow, thereby enhancing packing capacity. 4. Minimize friction - This helps an open shape that has good aerodynamic characteristics		
4b-ii	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. The rate of drying is given by $R = -\frac{W'}{A} \times \frac{dX}{dt}$ -----------------(1) $R = R_C$ = rate during constant rate period $R_C = -\frac{W'}{A} \times \frac{dX}{dt}$ ----------------(2) 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. $dt = \frac{W'}{A.RC} dX$ ----------------(3) Integrating Equation (3) between the limits : $t = 0, \quad X = X_1$		6

and t = t, $X = X_2$, we get

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

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

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

2

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 of X_C, then the time required during the entire constant rate period is given by

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

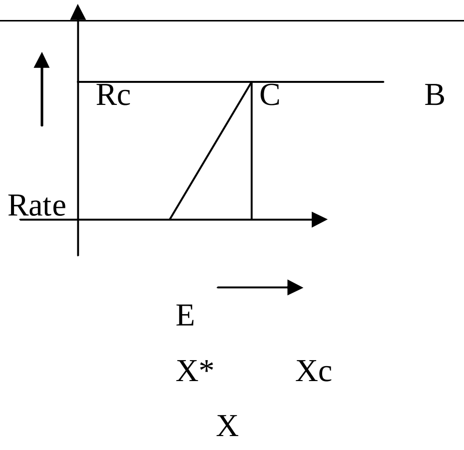
Falling rate period :

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

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

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

$$m = \frac{RC}{[XC - X^*]} \qquad \text{----------------(9)}$$

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

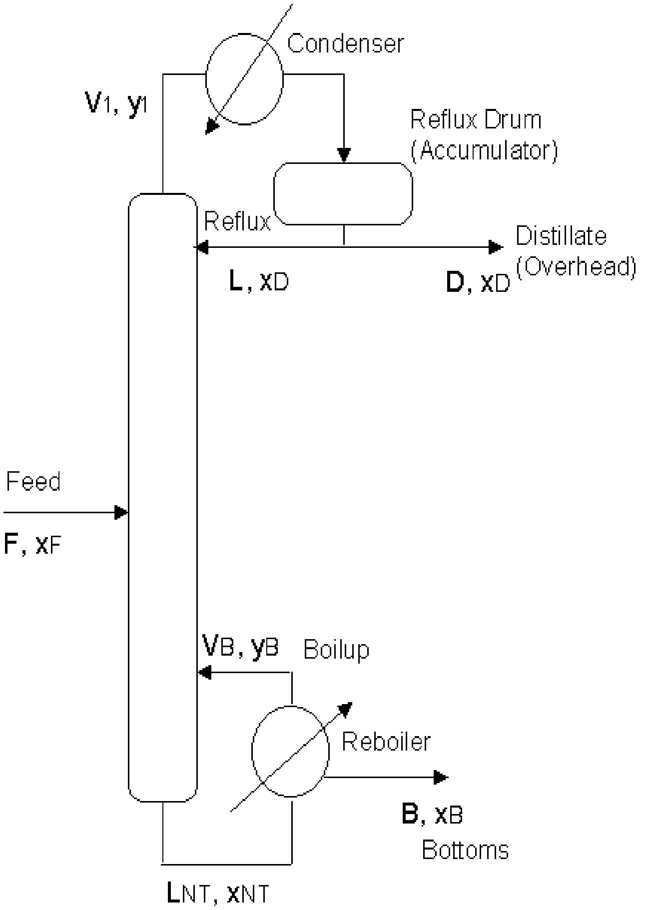
$$\int_{X1}^{X2} \frac{dX}{[X - X^*]} = \frac{RC\ A}{[XC - X^*]W'} \int_0^t t \qquad \text{----------------(12)}$$

2

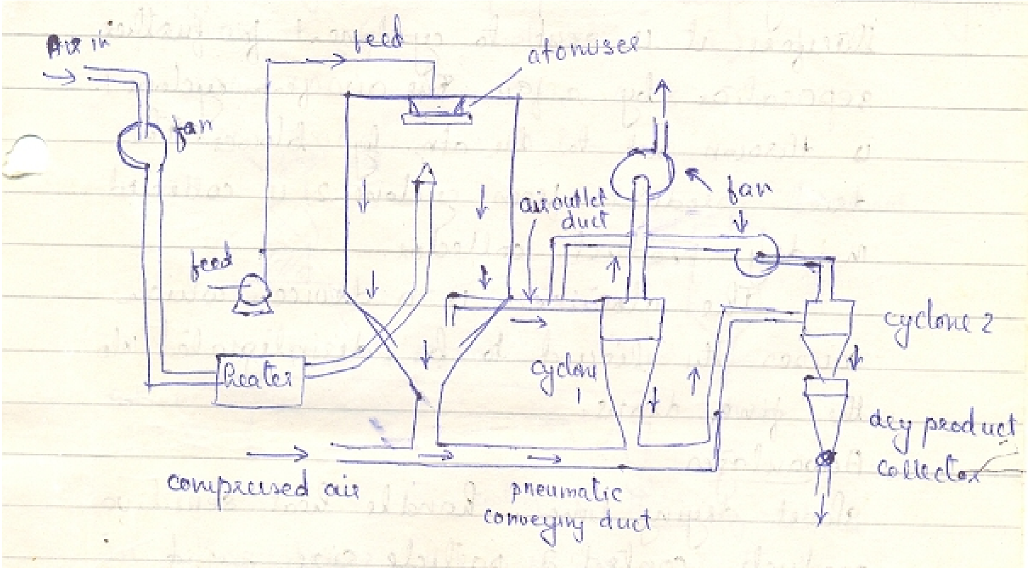
	$t = \frac{[XC - X^*]\, W'}{RC\ A} \ln \frac{X1 - X^*}{X2 - X^*}$ ----------------(13) Equation (13) gives the time of dying during the falling rate period to dry the material from X_1 to X_2. If the material is to be dried from the critical moisture content X_C to the final moisture content X_2 ($X_2 < X_C$), then the time required for drying during the entire falling rate period is given by t_f as : $t_f = \frac{[XC - X^*]\, W'}{RC\ A} \ln \frac{XC - X^*}{X2 - X^*}$ ----------------(14) [As X_1 becomes X_C] t_f = drying time during entire falling rate period. Total time of drying = $t_C + t_f$ $t = \frac{W'}{A.RC} [(X_1 - X_C) + (X_C - X^*)] \ln \frac{XC - X^*}{X2 - X^*}$ --------(15)	2	
5-a	An **azeotrope** is a mixture of two or more liquids whose proportions cannot be altered by simple distillation. This happens because, when an azeotrope is boiled, the vapor has the same proportions of constituents as the unboiled mixture. Ther methods of separation involve introducing an additional agent, called an *entrainer,* that will affect the volatility of one of the azeotrope constituents more than another. When an entrainer is added to a binary azeotrope to form a ternary azeotrope, and the resulting mixture distilled, the method is called azeotropic distillation. A well-known example of a positive azeotrope(**minimum boiling**) is	1 1	4

	95.63% ethanol and 4.37% water (by weight).[5] Ethanol boils at 78.4 °C, water boils at 100 °C, but the azeotrope boils at 78.2 °C, which is lower than either of its constituents An example of a negative azeotrope (**maximum boiling mixtures)** is hydrochloric acid at a concentration of 20.2% and 79.8% water (by weight). Hydrogen chloride boils at −84 °C and water at 100 °C, but the azeotrope boils at 110 °C, which is higher than either of its constituents	1 1	
5-b	**Comparison between packed and plate towers:** The choice between use of tray column or a packed column for a given mass transfer operation should, theoretically, be based on a detail cost analysis for the two types of contactors. However, the decision can be made on the basis of a qualitative analysis of relative advantages and disadvantages, eliminating the need for a detailed cost comparison. Which are: 1. Because of liquid dispersion difficulties in packed columns, the design of tray column is considerably more reliable. 2.Tray columns can be designed to handle wide ranges liquid rates without flooding. 3.If the operation involves liquids that contain dispersed solids, use of a tray column is preferred because the plates are more accessible for cleaning. 4. For non-foaming systems the plate column is preferred 5. Side streams are very easily taken from plate towers. 6. Whenever interstage cooling is required, plate towers are preferred. 7. Liquid hold up is low in packed towers 8. Pressure drop through packed tower is low.	1 mark each for any four	4
5-c	**Channeling in packed columns:** It is the tendency of the liquid to segregate towards the walls and to flow along the walls.	2	4

	or channeling is the unequal wetting of the packings in the tower. If channeling occurs, poor mass transfer happens, and therefore, less efficiency of the tower happens. Two methods to avoid channeling: 1. *Channeling* occurs when water flows down the *tower* wall rather through the void within packing. Using smaller-size *packing* will also *reduce* the tendency of flow to channel. *2.* The diameter of the tower should be at least eight times the packing size. 3. Good initial liquid distribution	1 mark each for any 2	

5-d	In reboiler the liquid bottom flow is converted to vapour just like a feed plate. Thus it is considered as an ideal plate. It does not happen in case of condenser.  	2 2	4
5-e	**HETP** In packed columns, mass transfer efficiency is related to intimate contact and rate transfer between liquid and vapor phases. The most used concept to evaluate the height of a packed column, which is related to separation efficiency, is the HETP (Height Equivalent to Theoretical Plate), defined by the	2	4

	following equation: Z=(HETP).(N) in which Z is the height of the packed bed necessary to obtain a separation equivalent to N theoretical stages. HETP is the height of a section of packing that will give the same separation as that achieved with one theoretical plate. **Factors on which HETP depends:** Type of feed mixture Feed conditions Process conditions Type of packing	2	
6-a	**The drying surface = 0.5m^2/kg dry solid (Assumed , not given in the problem)** **Any assumption for it should be given full marks.** X1= Initial moisture content on dry basis = 0.67/(1-0.67)=2.03 X2= final moisture content on dry basis = 0.25/(1-0.25)= 0.333 X*= Equilibrium moisture content = 0.01/(1-0.01)= 0.0101 Xc= Critical moisture content=0.40/(1-0.40)=0.67 Rate of drying in the constant rate period= Rc= 1.5kg/(m^2.h)	2 1	8

	Drying surface= **0.5m^2/kg dry solid** Therefore A/W'= 0.5 W'/A= 2.0 The time required for drying is $t = W'/(A\ Rc)[\ (X1-Xc)+(Xc-X^*)(\ln(Xc-X^*)/(X2-X^*))]$ $=2/1.5[(2.03-0.67)+(0.67-0.0101)\ \ln[(0.67-0.0101)/(0.333-0.0101)]]$ T=**2.44 h.**	1 2 2	
6-b	**Spray Dryer:**  It is continuous direct contact dyer employed for drying of solutions, slurries and pastes. In this dyer, the feed is introduced in the form of very fine droplets into a stream of hot gas.	3	8

	Construction& Working : The feed is pumped to the top of this dyer where it is disintegrated into small droplets by atomizes . The large quantity of fresh air is taken in by fan, it is heated in the heater and finally fed below the atomizer in drying chamber. As the surface area of drops is very large, the liquid portion of these drops rapidly evaporates and before they touch the bottom of drying chamber they are completely dried. The dried product is taken out and conveyed in the cyclones dust collector by stream of air major portion of the air is taken out through air outlet duct which mostly contains dust and is sent to cyclones. The solids collected are fed to pneumatic conveying duct. The air leaving the cyclone tomay contain some dust and therefore it is sent to cyclone 1 for further separation by a fan., The air from cyclone 1 is thrown out to the atmosphere by blower. The dried product from cyclone 2 is connected in dry product collector. **Application:** 1.Used for products such as milk powder, detergents, dyes, coffee, pharmaceuticals etc.	3 2	
6-c	Basis: 1000 kg of solution at 353 K F= 1000 kg Xf'=weight fraction of $MgSO_4$ in the feed		8

	= 64.2/164.2= 0.391		
	Water in the feed solution=F(1-Xf’)	2	
	= 1000(1-0.391)=609kg		
	V= kg of water evaporated during cooling		
	= 608x0.1=60.9 kg		
	X’=solubility of $MgSO_4$ at 303 k=40.8kg/100kg water		
	M1=Molecular weight of $MgSO_4$=120	2	
	M2= Molecular weight of $MgSO_4,7H_2O$=246		
	C=Yield of $MgSO_4,7H_2O$ crystals from feed solution		
	M2-M1=Water of crystallization=246-120=126kg		
	Material balance of $MgSO_4$		
	Xf’F=C.M1/M2+[F(1-Xf’)-V-C((M2-M1)/M2)]X’	2	
	$MgSO_4$ in feed= $MgSO_4$ in hydrated crystal+ $MgSO_4$ in mother liquor at 303 K		
	0.391(1000) = C (120/246) + [1000(1-0.391)-60.9-C(126)/246]40.8/100		
	391=0.488C+ [609-60.9-0.512C] (0.408)		
	C=599.7 kg	2	
	$MgSO_4,7H_2O$ yield=**599.7 kg**		