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-i	**Equation for steady state diffusion of gas A through non diffusing gas B:** $N=(D_{AB}\ P/RTZ\ P_{B,M})\ (P_{A1}-P_{A2})$ Where D_{AB} – diffusion coefficient P- total pressure R- gas constant Z – distance in the direction of diffusion $P_{B,M} – (P_{B2}-P_{B1}) / \ln(P_{B2}/P_{B1})$ P_{A1}- partial pressure of A at point 1 P_{A2}- partial pressure of A at point 2 **Derivation:** $N_A = J_A + x_A(N_A+N_B)$ For ideal gas $c_A = P_A/RT \quad dc_A = dP_A/RT \quad c = P/RT$ $N_A = -D_{AB}\ dc_A/dZ + c_A/c(N_A+N_B)$ $= -D_{AB} / RT(dP_A/dZ) + P_A/P\ (N_A+N_B)$ For steady state diffusion of A through non diffusing B N_A is constant and $N_B = 0$ $N_A = -D_{AB} / RT(dP_A/dZ) + P_A/P\ .\ N_A$ $N_A(P-P_A / P) = -D_{AB} / RT(dP_A/dZ)$ Or $N_A dZ = -D_{AB}\ P / RT(dP_A/P-P_A)$ Integrating,	1 1 1

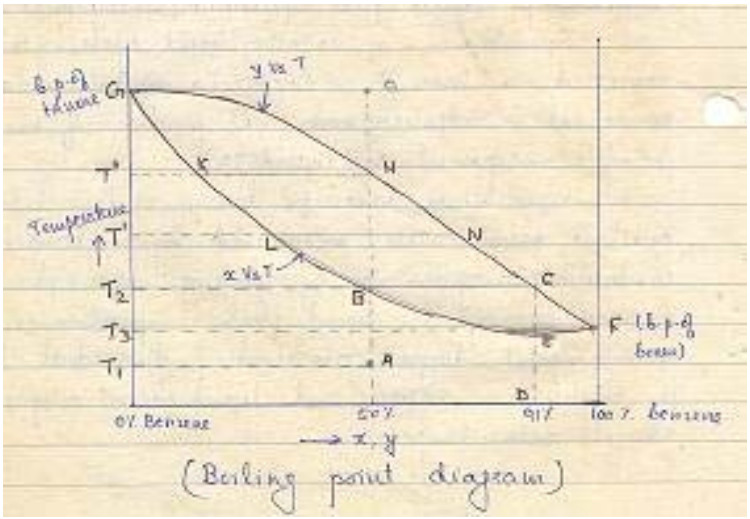
	$N_A = D_{AB} P / RTZ \ln[(P-P_{A2}) / (P-P_{A1})]$ But $P-P_{A2} = P_{B2}$ and $P-P_{A1} = P_{B1}$ Therefore $N_A = D_{AB} P / RTZ \ln[P_{B2} / P_{B1}]$ $N = D_{AB} P / RTZ \ln[P_{B2} / P_{B1}][(P_{B2} - P_{B1}) / (P_{B2} / P_{B1})]$ But $(P_{B2} - P_{B1}) / \ln(P_{B2} / P_{B1}) = P_{BM}$ & $(P_{B2} - P_{B1}) = (P_{A1} - P_{A2})$ Therefore **$N_A=(D_{AB} P/RTZ P_{B,M}) (P_{A1}-P_{A2})$**	1
1a-ii	$y= \alpha x/1+(\alpha-1)x$ $\alpha = 2.1$ calculate y for different values of x=0, 0.1,0.2…….1	1 3

x	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
y	0	0.19	0.34	0.47	0.58	0.67	0.76	0.83	0.89	0.95	1

1a-iii	**Fick** 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 D_{AB} – proportionality constant, diffusion coefficient Z – distance in the direction of diffusion **Importance of diffusion in mass transfer:** Diffusion is the movement of an individual component through a mixture from a region of higher concentration	2 2

	to a region of lower concentration at fixed temperature and pressure. A mixture which is non-uniform initially will be ultimately brought to uniformity by diffusion since the concentration gradient which acts as a driving force for distillation tends to move the component in such a direction as to equalize the concentrations and destroy the gradient. If we maintain the concentration gradient by constantly supplying the diffusing component to the high concentration end and removing it at the low concentration end, then the flow of diffusing component is continuous. This movement is utilized in mass transfer operations.	
1a-iv	**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. 1 Overall material balance is L=L-dL+dD Or dL= dD Material balance for component A is Lx=(L-dL)(x-dx)+ydD 1 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 $L=F$, $x=x_F$, $L=W$ $x=x_W$ $\int_{F}^{W} dL/L = \int_{xF}^{xW} dx/(y-x)$ $Ln(F/W) = \int_{x_F}^{x_W} dx/(y-x)$	1 1
1b	**Attempt any 1**	**6**
1b-i	**Steam distillation:** 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. **Application of Steam Distillation: (any 2)** 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.	4 1 mark each

1b-ii	**Boiling point diagram**  (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. 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	3 3

	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	**Attempt any 4**	16
2-a	**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 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.	1 mark each for any 4 points
2-b	**Differentiate between distillation and extraction: (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	1 mark each

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	

2-c **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

$$R = -\frac{dX}{dt} \times \frac{A}{L_s} \quad \text{----------(1)}$$ 1

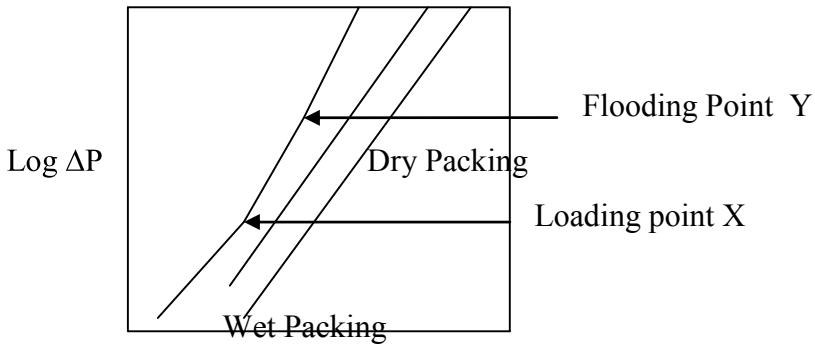
$R = R_C$ = rate during constant rate period

$$R_C = -\frac{dX}{dt} \times \frac{A}{L_s} \quad \text{----------(2)}$$

	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, $dt = \frac{W'}{A R_C} dX$ ----------(3) Integrating Equation (3) between the limits : $t = 0, \quad X = X_1$ and $t = t, \quad X = X_2$, we get $\int_0^t dt = -\frac{W'}{A R_C} \int_{X_1}^{X_2} dX$ ----------(4) $t = -\frac{W'}{A R_C}[X_2 - X_1]$ ----------(5) $t = \frac{W'}{A R_C}[X_1 - X_2]$ ----------(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 $t_C = \frac{W'}{A R_C}[X_1 - X_C]$ ----------(7)	1 1
2-d	**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 column 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. 1

The variation of pressure drop with gas velocity is plotted on log-log graph as shown in fig.



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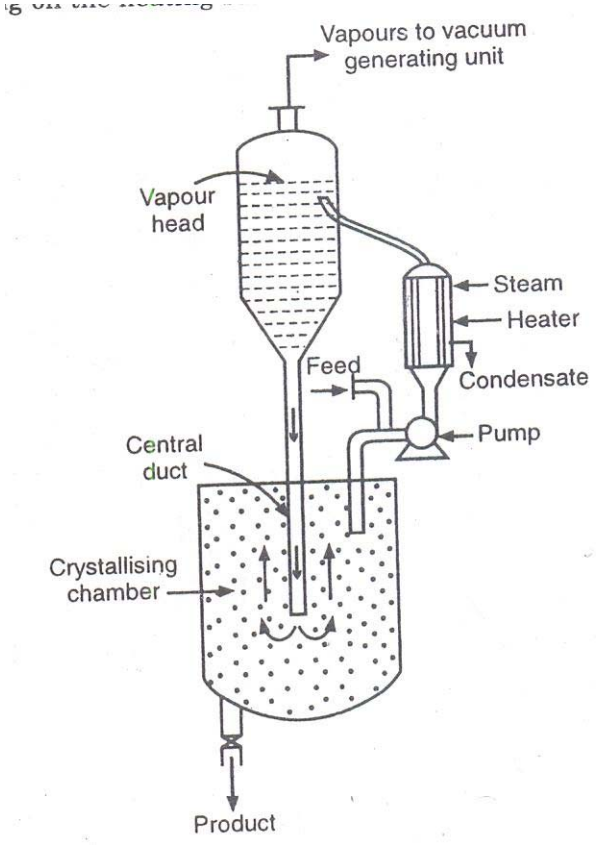
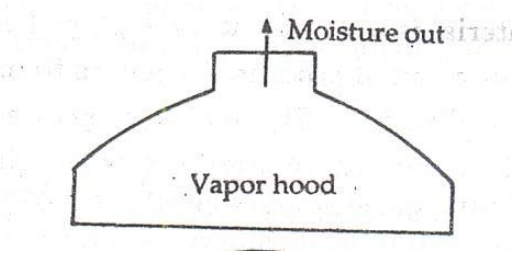
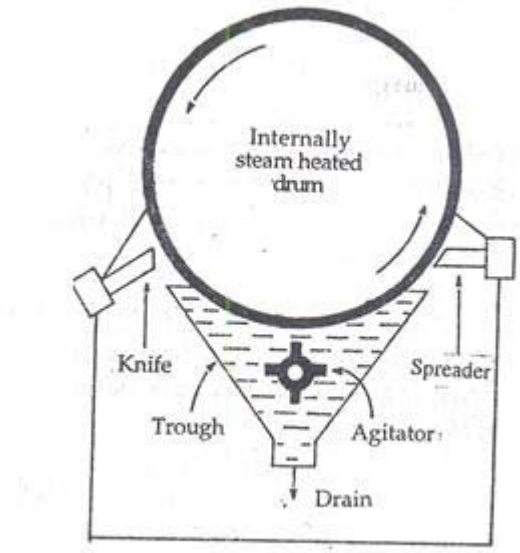
In case of dry packing, the relationship between pr.drop and gas velocity is represented by a straight line indicating that pressure drop is proportional to $G^{1.8-2}$. For wet packing, the relationship is indicated by straight line, but for a given velocity, pressure drop will be more than that for dry packing. 1

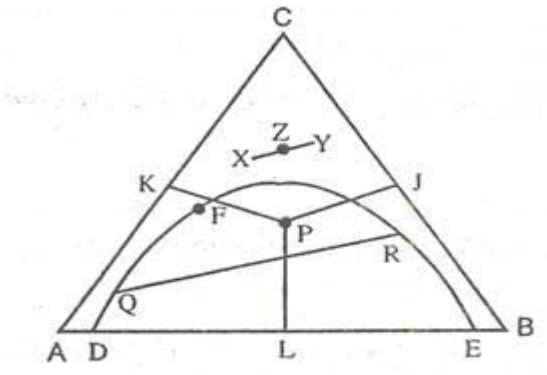
With the liquid flow down the tower at low and moderate gas velocities, pr.drop is proportional to 1.8^{th} power of gas velocity. Up to point X the amount of liquid held up in packing is constant. At point X the gas flow begins to impede the down flow of liquid and local accumulation of liquid appears 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.	1
2-e	**Oslo evaporative crystallizer:**  In this crystallizer, super saturation is generated or achieved by evaporation. **Construction:** It consist of a crystallizing chamber containing a bed of forming and growing crystals .A circulating pump and external heater for heating the solution with the help of condensing steam and a vapor head maintained by a vacuum generating equipment.	2 1

	Working: The solution from crystallizing chamber is pump by a circulating pump on the suction side of which the feed solution forming a small part of the total circulating liquid is introduced into a heater. Where it is heated by means of condensing steam and then fed to a vap head where some of the solution flashes into vap resulting into some degree of super saturation. The supersaturated solution is returned to the bottom of the crystallizing chamber through a central duct into a crystallizing chamber. Nucleation takes place in the crystal blade which is maintained In a fluidized state by means of upward flowing steam. Then the nuclei converted to crystal of required size and withdrawn as product from the bottom.	1
3	**Attempt any 2**	16
3-a	**Rotary drum Dryer:** **Construction**: It consists of a drum rotating in a tub of liquid to be filtered. The technique is well suited to slurries, and liquids with a high solid content, which could clog other forms of filter. The drum is pre-coated with a filter aid, typically of diatomaceous earth (DE) or Perlite. After pre-coat has been applied, the liquid to be filtered is sent to the tub below the drum. The drum rotates through the liquid and the vacuum sucks liquid and solids onto the drum pre-coat surface, the liquid portion is "sucked" by the vacuum through the filter media to the internal portion of the drum, and the filtrate pumped away. The solids adhere to the outside of the drum, which then passes a knife, cutting off the solids and a small portion of the filter media to reveal a fresh media surface that will enter the liquid as the drum rotates. The knife advances automatically as the surface is removed. A rotary vacuum filter consists of a large rotating drum covered by a cloth. The drum is suspended on an axial over a trough containing liquid/solids slurry with	3

	approximately 50-80% of the screen area immersed in the slurry. **Working**: As the drum rotates into and out of the trough, the slurry is sucked on the surface of the cloth and rotated out of the liquid/solids suspension as a cake. When the cake is rotating out, it is dewatered in the dying zone. The cake is dry because the vacuum drum is continuously sucking the cake and taking the water out of it. At the final step of the separation, the cake is discharged as solids products and the drum rotates continuously to another separation cycle.   	2 3
3-b	**Triangular diagram:**	



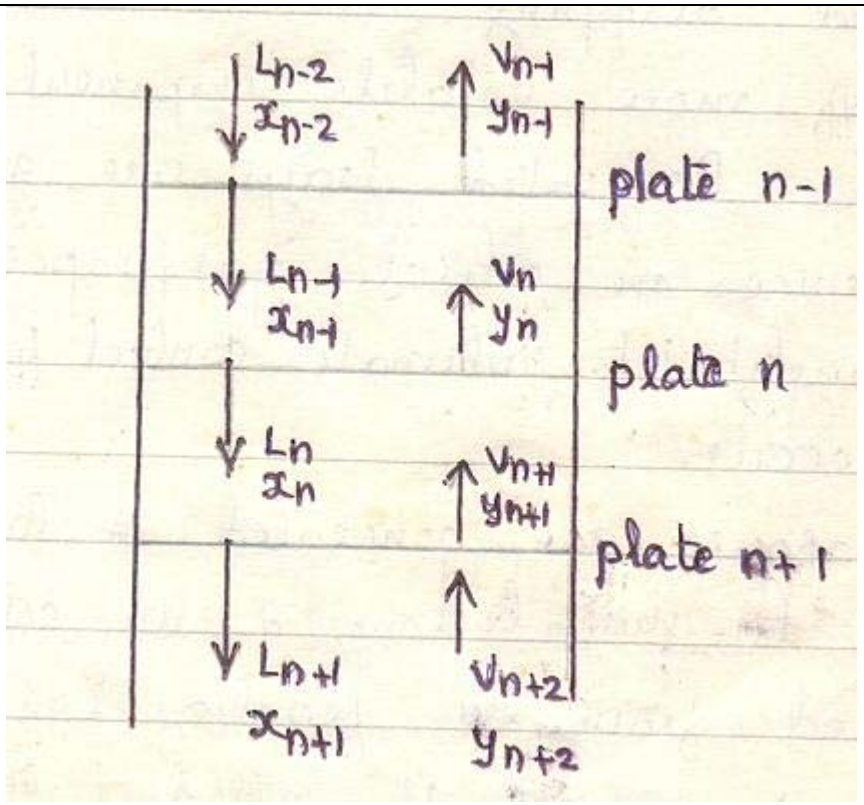
3

In liquid liquid extraction when the solvent is partially miscible with the original solvent , the solubility and equilibrium relations are often shown on a triangular diagram. The composition of ternary system can be shown by a point lying inside an equilateral triangle. Consider a system C (acetone).A (water),B (methyl isobutyl ketone) at 250C wherein acetone is solute , water is diluents and MIK is solvent for extracting the solute. Apex C in the triangle ABC represent 100% acetone and apex Aand B represent 100% water and 100% MIK respectively.Along line BC,concentration of Ais zero and the same is true for B and C along AC and AB.

4

The ternary system represented by point P consist of three components C,A,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 A in B. The curve the line ERF indicates composition of saturated MIK layer and the curve line DQF represent the composition of saturated water layer. The area under binodal solubility curve represented by the curve line DQFRE represent a two phase region that will splitup into two layers in equilibrium with each other.The point F on the curve represents a single phase which does not split into two phases and corresponds to tie line of zero length and is known as plate point.

	Use: In liquid - liquid extraction, when solvent is partially miscible with the original solvent, the solubility and equilibrium relations are shown on a triangular diagram. The composition of ternary systems can be shown by a point lying inside an equilateral triangle.	1
3-c	Initial moisture content X_1=0.35/(1-.0.35)=0.5385 Final moisture content X_2=0.1/(1-0.1)=0.111 Equilibrium moisture content X^*=0.04/(1-0.04)=0.0417 Critical moisture content X_c=0.14/(1-0.14)=0.1628 $t = W'/ARc \{ (X_1-X_c) + (X_c - X^*)\ln[(X_c - X^*)/(X_2 - X^*)]\}$ $5= W'/ARc \{ (0.5385-0.1628) + (0.1628 - 0.0417)\ln[(0.1628-0.0417)/(0.111 - 0.0417)]\}$ W'/Arc= 11.28 For second case X2 = 0.06/(1-0.06)=0.0638 $t= 11.28 \{ (0.5385-0.1628) + (0.1628 - 0.0417)\ln[(0.1628-0.0417)/(0.0638 - 0.0417)]\}$ **t = 6.56 hr.**	2 1 1 1 1 2
4 a	**Attempt any 3**	12
4a-i	**Rectification on ideal plate:**	



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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

2

	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.	
4a-ii	**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.	1 mark each
4a-iii	**Caking of crystals:** Caking of crystalline material is caused by to a small amount of dissolution occurring at the surface of crystals and subsequent re-evaporation of the solvent. Due to caking the crystals can get tightly bonded together. **Effect of impurities on crystal formation:** i) Soluble impurities may get adsorbed on the surface of the nuclei or crystals nucleation sites and retard the rate of nucleation and crystal growth. ii) The shape of crystal may get modified as adsorption of impurities may occur preferentially on a particular face, iii) The impurities may decrease the rate of crystal growth. In some	2 2

	cases, it is desirable . iv) Addition of a small quantity of glue or tannin to boiler feed water prevents nucleation and growth of carbonate crystals and thus reduces scaling.	
4a-iv	Different types of packings are : 1) Raschig rings. 2) Pall rings. 3) Hy-pak. 4) Berl saddles. 5) Intalox saddles. 6) Super intalox saddles 7) Lessing ring **Characteristics of a tower packing :** 1) It should provide a large interfacial area for phase contacting 2) It should possess good wetting characteristics. 3) It should have a high corrosive resistance. 4) It should be relatively cheap. 5) It should possess enough structural strength. 6) It should be chemically inert to the fluids handled in the tower.	½ mark each for any 4 ½ mark each for any 4
4b	**Attempt any 1**	**6**
4b-i	**q-line:** The 'q' is a measure of the thermal condition of the feed and is defined as the number of moles of saturated liquid resulting in the stripping section for each mole of feed introduced. Thus for a feed we get , L' = L + qf V = V' + (1-q)F **Derivation of q-line :**	3

The liquid flow in the stripping section is

$$L' = L + qf$$

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

Similarly, the vapour flow in the rectifying section is

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

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

Overall material balance in the upper section of coloumn :

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

Material balance of A in the upper section :

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

Overall material balance in the lower section :

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

Material balance of A in the lower section :

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

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 :

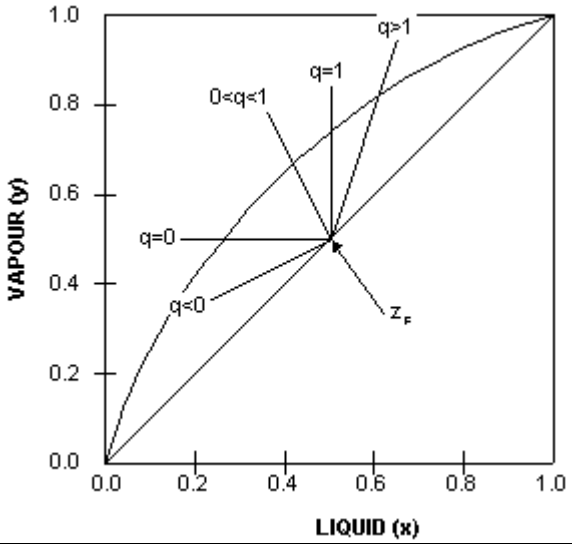
$$x_f . F = D x_D + W x_w \quad \text{---------- (9)}$$

Equation (8) becomes

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

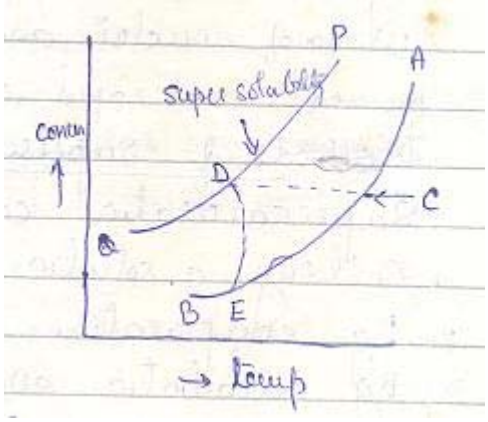
Substituting the values of V - V' and L' – L from Equation (3) and (1) into Equation (10) gives

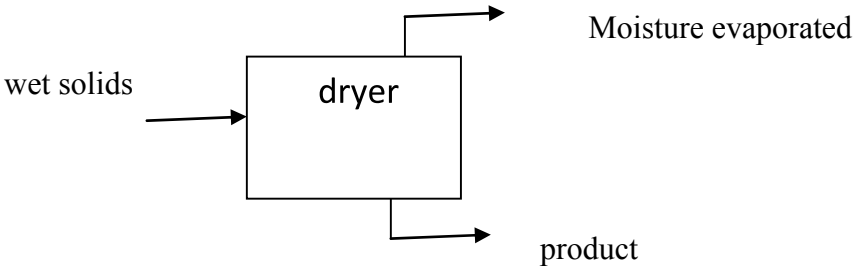
$$y (1 - q) F = x(-qF) + x_F . F$$

	$y = \frac{\quad}{\quad}x + \frac{\quad}{\quad}$ ---------- (11) Equation (11) is known as the **feed line or q-line** equation **Types of q lines for various feed conditions:** q = 0 (saturated vapour) q = 1 (saturated liquid) 0 < q < 1 (mix of liquid and vapour) q > 1 (subcooled liquid) q < 0 (superheated vapour)  	3
4.b ii	**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.	1 mark each for any 6 points

	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 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.	
5	**Attempt any4**	**16**
5-a	**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
	Channeling: The tendency of liquid to segregate towards the walls and to flow along to walls (region of greatest void space) is termed as channeling which lead to low mass transfer efficiencies. **It can be prevented** by:	2

	1. Providing tower diameter to packing size ratio greater than 8 2. Providing good liquid distribution system. **Channeling leads to flooding and loading:** When channeling occurs, liquid flows along the walls and liquid hold up in the column starts to increase. This is loading. When the gas velocity increases further, entrainment of liquid by the gas leaving the top of the tower increases and flooding of tower takes place.	
5-b	 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 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.	3

		1
5-c	Basis : 1000m^3/hr of gas mixture to absorption tower. n= PV / RT = 106.6*1000 / 8.314*300 = 42.76 kmol/h Solute in the gas entering = 0.1*42.76 = 4.276 kmol/h Inert gas at the inlet = 42.76- 4.276 = 38.484 kmol/h Solute absorbed = 0.9*4.276 = 3.848 kmol/h X_1 = solute composition at bottom = 0.05/(1-0.05) = 0.0526 X_2 = solute composition at top = 0 Y_1 = solute composition in inlet gas to tower = 0.1/(1-0.1) = 0.111 Y_2= solute composition in outlet gas from tower = 0.428/ 38.484 = 0.011 L' = mass flowrate of solute free solvent in kg/hr V'= mass flowrate of solute free gas or air in kg/hr V' (Y_1-Y_2) = L' (X_1-X_2) 38.484 (0.111 - 0.011) = L' (0.526 - 0) L' = 73.09 kmol/hr Molar flow rate of water = **73.09 kg/hr**	1 1 1 1

5-d	 Basis: 100 kg dried product Let X kg wet solids and Y kg moisture evaporated Overall balance is X = Y + 100 Solid balance is 0.2 X = 0.95* 100 Or X = 475 kg moisture evaporated 475-100 = **375 kg**	1 1 1 1
5-e	**Solution**: The flux for equimolar counter diffusion is given by, $N_A = D_{AB} P(pA1-pA2)/ RTz P_{BM}$ Where, $D_{AB} = 1.81*10^{-5}$ m^2/s, R= 8.31451 m^3. kPa/ (kmol. K) T = 298 K , z= 2mm=0.002m $p_{A1} = 0.2*101.3=20.26kPa$, $p_{A2}= 0.1*101.3 = 10.13$ kPa $P_{B1} = P- p_{A1} = 101.3-20.26 = 81.04$ kPa $P_{B2} = P- p_{A2} = 101.3-10.13 = 91.17$ kPa $P_{BM} = (P_{B2}- P_{B1}) / \ln (P_{B2}/ P_{B1})$ $= (91.17-81.04) / \ln(91.17.81.04) = 86$ kPa $N_A = 1.81*10^{-5} (20.26-10.13) 101.3/8.31451*298*0.002*86$ = **$4.358*10^{-5}$ kmol/(m^2.s)**	 1 1 1 1
6	**Attempt any 2**	**16**
6-a	Basis 1000 kg feed solution at 353K	

	F=1000 kg. x_F=64.2/164.2= 0.391	1
	Water in feed = 1000(1-0.391) = 609 kg	
	Water evaporated = 0.1*609= 60.9 kg	1
	Mol wt of $MgSO_4$=120, Mol wt of $MgSO_4 7H_2O$ = 246	1
	Solvent balance is	
	$F(1- x_F) = V+C8(126/246)+ L$	1
	100 (1-0.391)=60.9+0.5122C+L	
	or L=609-60.9+0.5122C kg.	1
	$MgSO_4$ balance	
	$MgSO_4$in feed = $MgSO_4$ crystals + $MgSO_4$ in mother liquor.	1
	0.391*1000=C(120/246)+[609-60.9+0.5122C] * solubility of $NaNO_3$	
	391 = 0.488C+[609-60.9+0.5122C]*0.408	1
	Or C=599.7 kg	
	Yield of $MgSO_4$ crystals **(C)=599.7 kg.**	1
6-b	Basis: 100 kmol feed	
	D= 60, W=40 x_F=0.4	1
	Plot 1/(y-x) vs x	1
	Ln(F/W)= ln(100/40)= 0.916	1
	From the graph measure the area under curve from x_F=0.4 till area equals 0.916	
	and the corresponding value of x is noted as x_W.	2
	x_W = 0.07	
	$Fx_F=Dx_D=Wx_W$	1
	100*0.4= 60*x_D+ 40*0.07	
	Solving the equation **x_D** = 0.62	1
	Composition of distillate = 62%	
	Composition of residue = 7%	1
6-c	**Basis:** Feed containing 40% benzene and 60% toluene	

	Molecular weight of benzene=78 Molecular weight of toluene= 92 Xf= mole fraction of benzene in the feed = (40/78)/(40/78 + 60/92) =0.44 Similarly xd= (96/78)/(96/78+4/92)=0.966 Xw= (5/78)/(5/78+95/92)=0.058 Relative volatility = α= 2.5 With the help of relative volatility, generate x-y data and plot the equilibrium diagram. For generating x-y data assume X= 0,0.1,0.2,……1 and find the corresponding values of y from the relation Y= α x/(1+(α-1)x Procedure for finding out the minimum reflux ratio q=1/3 slope of feed line=-(q/1-q)= -0.5 Intercept on y axis=xf/(1-q) =0.66 Draw the feed line through the point (0.44,0.44) on the diagonal with a slope equal to -0.5 or intercept equal to 0.66 which will cut the equilibrium curve at point P. Through the point A(0.966,0.966) on the diagonal ,draw the operating line A-P of the rectification section (dotted line) and read y' and x' on y axis and x axis respectively. Minimum reflux ratio Rm= (x_D-y') / (y'-x') From graph y'=0.515, x'=0.3 Rm= 2.1 R=1.5Rm=1.5x 2.1=3.14 Operating line of rectification section:	1 1 1 1 1

	Point A(0.966,0.966) on the diagonal.	
	The intercept of the rectifying section of operating line is = x_D /R+1 =0.966/3.14+1=0.232	1
	From the graph the theoretical stages required including reboiler = n=10.	1
	Number of stages required in column=n-1=**10-1=9**	1