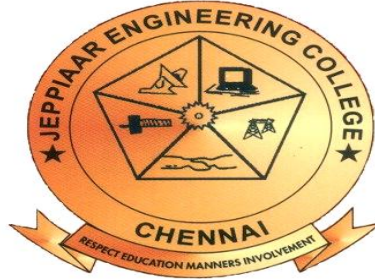


JEPPIAAR ENGINEERING COLLEGE



B.TECH – BIOTECHNOLOGY (R- 2013)

BT6503 MASS TRANSFER OPERATION

III YEAR & V SEM

BATCH: 2016-2020

QUESTION BANK

PREPARED BY

A.MUTHULAKSHMI

VISION OF THE INSTITUTION	
❖ To build Jeppiaar Engineering College as an institution of academic excellence in technological and management education to become a world class University	
MISSION OF THE INSTITUTION	
❖ To excel in teaching and learning, research and innovation by promoting the principles of scientific analysis and creative thinking. ❖ To participate in the production, development and dissemination of knowledge and interact with national and international communities . ❖ To equip students with values, ethics and life skills needed to enrich their lives and enable them to meaningfully contribute to the progress of society . ❖ To prepare students for higher studies and lifelong learning , enrich them with the practical and entrepreneurial skills necessary to excel as future professionals and contribute to Nation's economy	
VISION OF THE DEPARTMENT	
To pursue excellence in producing bioengineers coupled with research attributes.	
MISSION OF THE DEPARTMENT	
M1	To impart quality education and transform technical knowledge into career opportunities.
M2	To establish a bridge between the program and society by fostering technical education.
M3	To generate societal conscious technocrats towards community development
M4	To facilitate higher studies and research in order to have an effective career / entrepreneurship .
PROGRAM EDUCATIONAL OBJECTIVES (PEOS)	
PEO - 1	To impart knowledge and produce competent graduates in the field of biotechnology
PEO - 2	To inculcate professional attributes and ability to integrate engineering issues to broader social contexts.
PEO - 3	To connect the program and community by fostering technical education.
PEO - 4	To provide a wide technical exposure to work in an interdisciplinary environment
PEO - 5	To prepare the students to have a professional career and motivation towards higher education.

	PROGRAM SPECIFIC OUTCOMES (PSOS)
PSO 1	Professional Skills: This programme will provide students with a solid foundation in the field of Biological Sciences and Chemical engineering enabling them to work on engineering platforms and applications in Biotechnology as per the requirement of Industries, and facilitating the students to pursue higher studies
PSO 2	Problem-solving skills: This programme will assist the students to acquire fundamental and problem solving knowledge on subjects relevant to Biotechnology thereby encouraging them to understand emerging and advanced concepts in modern biology
PSO 3	Successful Career and Entrepreneurship: Graduates of the program will have a strong successful career and entrepreneurial ability with the blend of inputs from basic science, engineering and technology, thereby enabling them to translate the technology and tools in various industries and/or institutes

	PROGRAM OUTCOMES (PO)
PO 1	Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO 2	Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO 3	Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations
PO 4	Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO 5	Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
PO 6	The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
PO 7	Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO 8	Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO 9	Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO 10	Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO 11	Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO 12	Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

OBJECTIVES:

- To define the principles of adsorption, absorption, leaching and drying extraction, distillation, crystallization operations.
- To begin the concept of membrane separation process and develop skills of the students in the area of mass transfer operations with emphasis on separation and purification of products.

UNIT I **DIFFUSION AND MASS TRANSFER** **9**
Molecular diffusion in fluids and solids; Interphase Mass Transfer; Mass Transfer coefficients; Analogies in Transport Phenomenon.

UNIT II **GAS LIQUID OPERATIONS** **9**
Principles of gas absorption; Single and Multi component absorption; Absorption with Chemical Reaction; Design principles of absorbers; Industrial absorbers; HTU, NTU concepts.

UNIT III **VAPOUR LIQUID OPERATIONS** **9**
V-L Equilibria; Simple, Steam and Flash Distillation; Continuous distillation; McCabe-THIELE & PONCHON-SAVARIT Principles; Industrial distillation equipments, HETP, HTU and NTU concepts.

UNIT IV **EXTRACTION OPERATIONS** **9**
L-L equilibria, Staged and continuous extraction, Solid-liquid equilibria, Leaching Principles.

UNIT V **SOLID FLUID OPERATIONS** **9**
Adsorption equilibria – Batch and fixed bed adsorption; Drying-Mechanism-Drying curves-Time of Drying; Batch and continuous dryers.

TOTAL : 45

PERIODS**OUTCOMES:**

Upon completion of this course the students will be able

- To demonstrate about gas -liquid, vapour- liquid and solid- liquid and liquid-liquid equilibrium.
- To classify and use the accurate engineering correlations of diffusion and mass transfer coefficients to model a separation process.
- To investigate a multi-stage equilibrium separation processes, simultaneous phase equilibrium and mass balances in continuous separation processes (absorbers, strippers, and distillation columns) and sizing continuous separation units.
- To design and construction with operating principles of process economics of separating equipments

TEXT BOOKS:

1. Treybal R.E. Mass Transfer Operations. 3rd edition. McGraw Hill, 1981.
2. Geankoplis C.J. Transport Processes and Unit Operations. 3rd edition, Prentice Hall of India, 2002.

REFERENCE:

1. Coulson and Richardson's Chemical Engineering. Vol I & II, Asian Books Pvt Ltd, 1998.

BT 6503 MASS TRANSFER OPERATION

CO NO.	COURSE OUTCOMES
C503.1	students will be able To demonstrate about gas -liquid, vapour- liquid and solid- liquid and liquid–liquid equilibrium
C503.2	students will be able To classify and use the accurate engineering correlations of diffusion and mass transfer coefficients to model a separation process
C503.3	Students will be able To investigate a multi-stage equilibrium separation processes, simultaneous phase equilibrium and mass balances in continuous separation processes (absorbers, strippers, and distillation columns) and sizing continuous separation units.
C503.4	students will be able To design and construction with operating principles of process economics of separating equipments
C503.5	students will be able Gain the knowledge on the concept of membrane separation process

**BT6503 MASS TRANSFER OPERATION
LESSON PLAN**

S. No.	Title	Reference Book	Page No.
UNIT I DIFFUSION AND MASS TRANSFER			
1.	Molecular diffusion in fluids and solids;	Treybal , Mass Transfer Operations	21-40
2.	Interphase Mass Transfer;	Treybal , Mass Transfer Operations	104-113
3.	Mass Transfer coefficients;	Treybal , Mass Transfer Operations	45-66
4.	Analogies in Transport Phenomenon.	Treybal , Mass Transfer Operations	66-70
UNIT II GAS LIQUID OPERATIONS			
1.	Principles of gas absorption	Treybal , Mass Transfer Operations	275-280
2.	Single and Multi component absorption	Treybal , Mass Transfer Operations	277-295
3.	Absorption with Chemical Reaction	Treybal , Mass Transfer Operations	333
4.	Design principles of absorbers	Treybal , Mass Transfer Operations	283-291
5.	Industrial absorbers	Treybal , Mass Transfer Operations	186-195
6.	HTU, NTU concepts	Treybal , Mass Transfer Operations	301-314
UNIT III VAPOUR LIQUID OPERATIONS 9			
1.	V-L Equilibria	Treybal , Mass Transfer Operations	343-362
2.	Simple, Steam and Flash Distillation;	Treybal , Mass Transfer Operations	363-369
3.	Continuous distillation; McCABE-THIELE & PONCHON-SAVARIT Principles	Treybal , Mass Transfer Operations	374-379 402-412
4.	Industrial distillation equipments	Treybal , Mass Transfer Operations	371-374
5.	HETP, HTU and NTU concepts.	Treybal , Mass Transfer Operations	426-429
UNIT IV EXTRACTION OPERATIONS 9			
1.	L-L equilibria	Treybal , Mass Transfer Operations	477-489
2.	Staged and continuous extraction	Treybal , Mass Transfer Operations	490-502
3.	Solid-liquid equilibria	Geankoplis, Transport Processes	809-811
4.	Leaching Principles.	Treybal , Mass Transfer Operations	717-744
UNIT V SOLID FLUID OPERATIONS 9			
1.	Adsorption equilibria	Treybal , Mass Transfer Operations	565-583
2.	Batch and fixed bed adsorption	Treybal , Mass Transfer Operations	585-595

3.	Drying-Mechanism	Treybal , Mass Transfer Operations	655-661
4.	Drying curves	Treybal , Mass Transfer Operations	667-670
5.	Time of Drying	Treybal , Mass Transfer Operations	670-672
6.	Batch and continuous dryers.	Treybal , Mass Transfer Operations	662-666

ANNA UNIVERSITY SOLVED QUESTION PAPER NOV/DEC 2017

PART A

1. Define molecular diffusion.

Molecular diffusion is caused by the movement of individual molecules through a substance by virtue of their thermal energy.

*Eg:- if coloured solution is poured into a pool of water it begins to diffuse slowly into the entire liquid

2. State Fick's Law of Diffusion.

Fick's first law of diffusion states that the molar flux (J) of diffusion is directly proportional to the concentration gradient.

$$J_A = -D_{AB} \frac{\partial C_A}{\partial Z}$$

- D_{AB} is diffusivity or diffusion coefficient for component A.
- $\frac{\partial C_A}{\partial Z}$ is concentration gradient.
- -ve sign indicates that the diffusion occurs in the direction of drop in concentration.

3. Write the material balance equation in counter current absorption.

The liquid enters from top of the column whereas gas is added from the bottom of the column.

Overall material balance:

$$G_s (Y_{N+1} - Y_1) = L_s (X_N - X_0)$$

This is the operating line for counter current absorption tower.

4. What is the effect of pressure and temperature on absorption?

Increasing the temperature of the system the amount of gas that can be absorbed by liquid decreases, while with increasing the pressure generally absorption increases.

5. What is "Relative volatility"? Give expression for a binary mixture.

It is the ratio of the vapor pressure of 'A' to the vapor pressure of 'B' at the same temperature.

$$\alpha = \frac{(1-x)y^*}{(1-y^*)x} \quad \alpha = \frac{P_A}{P_B}$$

6. Write the total material and component balance for two component system of the entire distillation column.

Overall material balance over the entire distillation column:

$$F = D + B$$

Where F= Feed, D= Top product (or) Distillate, B = Bottom product (or) Residue.

Component balance over the entire distillation column:

$$F x_F = D x_D + B x_B$$

Where x_F , x_D , and x_B = Mole fraction of feed, distillate and residue respectively.

7. What is "Distribution Coefficient"?

Distribution coefficient is defined as the ratio of y^* to x at equilibrium i.e. $= \frac{y^*}{x}$

Where, X = concentration of A in the liquid, mole fraction

$Y^* = y$ is equilibrium with x , mole fraction

Y = concentration of A in the gas, mole fraction

Large values of distribution coefficient are very desirable since less solvent will then be required for the extraction.

8. What are the factors depends on leaching action?

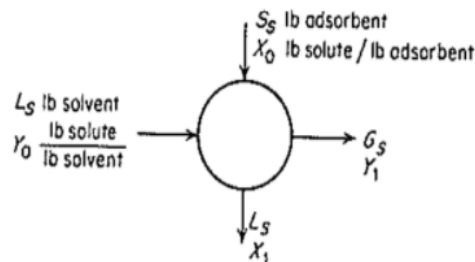
- (i) Particle size.
- (ii) Temperature.
- (iii) Concentration of reagent.
- (iv) Stirring/Agitation rate.

9. Distinguish between physical adsorption and chemisorption.

Physisorption	Chemisorption
Forces of attraction are van der Waals' forces	Forces of attraction are chemical bond forces
Low enthalpy of adsorption (20 - 40 kJ/mole)	High enthalpy of adsorption (200 - 400 kJ/mole)
This process is observed under conditions of low temperature	This process takes place at high temperatures
It is not specific	It is highly specific
Multi-molecular layers may be formed	Generally, monomolecular layer is formed
This process is reversible	This process is irreversible

10. Write the material balance for the single stage adsorption operation.

Material balance for the single stage adsorption:



$$L_S (Y_0 - Y_1) = S_S (X_1 - X_0)$$

L_S – Mass of unadsorbed substance or solvent (mass/time)

S_S – Mass adsorbate –free solid. (Mass/time)

PART B

11. (a) Discuss in detail about various theories of mass transfer. [Treybal, Mass Transfer Operations, Page.No.59-64] (OR)
 (b) Derive the Reynolds analogy starting from fundamental transport equation for momentum, heat and mass. State the assumption made and limitations of the equation. [Treybal, Mass Transfer Operations, Page.No.64-66]
12. (a) A soluble gas is absorbed in water using packed tower. The equilibrium relationship is

$Y_e = 0.06 X_e$ and terminal conditions are:

	Top	Bottom
X	0	0.08
y	0.001	0.009

If the individual height of transfer units based on liquid phase and gas phase respectively are $H_x = 0.24$ m and $H_y = 0.36$ m, determine the height of packing. (Refer class notes) (OR)

- (b) Explain in detail about the various types of industrial absorbers with neat sketch. [Treybal, Mass Transfer Operations, Page No.282-285]
13. Derive Rayleigh equation in a Differential Distillation [Treybal, Mass Transfer Operations, Page.No.363-365] (OR)
 (b) Write briefly about the procedure to determine the number of theoretical plates required in the distillation column using the Ponchon Savarit method. [Treybal, Mass Transfer Operations, Page.No.402-412]
14. (a) (i) Discuss briefly about the qualities to be considered for the selection of the solvent in extraction. [Treybal, Page No.488-489]
 (ii) Nicotine I in a water (A) solution containing 1% Nicotine is to be extracted with kerosene (B) at 20°C. Water and kerosene are essentially insoluble:
 (a) Determine the percentage extraction of Nicotine if 100 kg of feed solution is extracted once with 150 kg of solvent.
 (b) Repeat their theoretical extractions using 50 kg solvent each. [Treybal, Page No.497]

Equilibrium data:

X' = kg nicotine/kg of water	0	0.0010	0.0025	0.0050	0.0075	0.0100	0.0204
Y' = kg nicotine/kg of kerosene	0	0.0008	0.0020	0.0046	0.0069	0.0091	0.0187

(OR)

- (0) Explain in detail about the total material balance for the Single stage and Multistage Counter Current Extraction with neat sketch. [Treybal, Page No.496-500]
15. (a) Give a brief note on various types of batch and fixed bed adsorption equipments available for adsorption of a solute from gaseous and liquid stream with neat sketch. [Treybal, Page.No.623-625] (OR)
 (i) Explain in detail about drying rate curve. [Treybal, Page No.667-676]
 (ii) Illustrate the material and energy balance expressions for continuous direct heat dryer. [Treybal, Page No.667-676]

PART – C

16. (a) A continuous fractionating column is to be designed to separate 30,000 kg/hr of a solution of benzene and toluene, containing 0.4 mass fraction of benzene into an overhead product containing 0.97 mass fraction of benzene and a bottom product containing 0.98 mass fraction of toluene. A reflux ratio of 3.5 kg of reflux per kg of product is to be used. The feed will be liquid at its boiling point and the reflux will be returned to the column:

- (i) Determine the top and bottom product
- (ii) Determine the number of theoretical stages needed using McCabe Thiele method:

x	0.77 3	0.65 9	0.55 5	0.45 9	0.37 0	0.28 8	0.21 1	0.14 1	0.07 5	0.01 3
y	0.89 7	0.83 1	0.75 7	0.67 8	0.59 1	0.49 6	0.39 3	0.28 1	0.16 1	0.03 1

(Refer class notes)(OR)

- (c) Give a detailed note on various types of batch and continuous dryers with neat sketch. [Treybal, Page No.662-664, 695]

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UNIT I DIFFUSION AND MASS TRANSFER PART A

1. Define molecular diffusion. (NOV/DEC 2016, 2013,2011)
Molecular diffusion is caused by the movement of individual molecules through a substance by virtue of their thermal energy.

*Eg:- if coloured solution is poured into a pool of water it begins to diffuse slowly into the entire liquid

2. State Fick's Law of Diffusion.(NOV/DEC 2016) (APR/MAY 2015,2010)(MAY/JUNE 2013,2009)(NOV/DEC 2008,2006)
Fick's first law of diffusion states that the molar flux (J) of diffusion is directly proportional to the concentration gradient.

$$J_A = -D_{AB} \frac{\partial C_A}{\partial Z}$$

- D_{AB} is diffusivity or diffusion coefficient for component A.
 - $\frac{\partial C_A}{\partial Z}$ is concentration gradient.
 - -ve sign indicates that the diffusion occurs in the direction of drop in concentration.
3. How the eddy diffusion is differentiated from molecular diffusion? (APR/MAY 2015) or distinguish between molecular diffusion and eddy diffusion. (APR/MAY 2010)

Molecular Diffusion	Eddy Diffusion
*It is caused by the movement of individual molecules through a substance by virtue of their thermal energy.	*When the diffusion process is processed by mechanical agitation, it is known as Eddy or turbulent diffusion.
*Eg:- if coloured solution is poured into a pool of water it begins to diffuse slowly into the entire liquid	*Eddy diffusion is also called as turbulent diffusion. Molecules move in a particular manner due to agitation.

4. What is the effect of temperature in diffusivity of gases? (NOV/DEC 2014,2013,2008)

Effect of temperature:

The diffusion coefficient D is a function of both temperature and pressure. Diffusion increases with increasing temperature (as molecules move more rapidly), and decreases with increasing pressure (which packs more molecules in a given volume, making it harder for them to move).

5. What is the effect of pressure in diffusivity of gases? (NOV/DEC 2014,2013,2008)

Effect of pressure:

Pressure dependence of diffusivity is given by

$$D_{AB} \propto \frac{1}{P} \quad [\text{For moderate ranges of pressure, upto 25 atm}]$$

i.e., the diffusivity is inversely proportional to the effect of pressure.

If pressure increases then diffusivity decreases.

6. State Reynolds analogy. (NOV/DEC 2014) (MAY/JUNE 2013)

Reynolds analogy is used to relate turbulent momentum and heat transfer. The main assumption is that heat flux (q/A) in a turbulent system is analogous to momentum

flux τ , which suggest that the ratio $\frac{\tau}{q/A}$ must be constant for all radial positions.

The Reynolds analogy is

$$\frac{f}{2} = \frac{h}{\rho C_p u_0} = \frac{k_c}{u_0}$$

7. What is eddy diffusion? (NOV/DEC 2012,2011,2009)

When mechanical agitation is provided to enhance the role of mixing, it causes turbulent motions, this type of diffusion is called as eddy or turbulent diffusion .

Eddy diffusion depends on the flow pattern, velocity, position of the flowing stream, physical properties, physical mixing and eddies in the turbulent zone.

8. What is meant by gas film controlling the mass transfer? (NOV/DEC 2012)

Equation for overall mass transfer coefficient in gas phase is given as

$$\frac{1}{K_y} = \frac{1}{k_y} + \frac{m}{k_x}$$

The term $1/K_y$ is the resistance to mass transfer in gas films.

If $\frac{1}{k_y} \gg \frac{m}{k_x}$, $K_y \approx k_y$.

This controls the mass transfer. Eg: NH_3 & HCl adsorbed by water.

9. Write down the relationship between mass transfer coefficients and diffusivity. (NOV/DEC 2011)

The diffusivity or diffusion coefficient, D_{AB} is defined as the ratio of its flux J_A to its concentration gradient.

Diffusion coefficient is a measure of diffusive mobility.

The negative sign emphasizes that diffusion occurs in the direction of a drop in concentration.

$$J_A = -D_{AB} \frac{\partial C_A}{\partial Z}$$

Where, J_A = molar flux

D_{AB} = diffusion coefficient

$\frac{\partial C_A}{\partial Z}$ = concentration gradient

10. Define molar flux and give its units. (NOV/DEC 2010)

It is defined as the rate of mass transfer across a unit area i.e.; the area being measured in the direction normal to the diffusion.

$$\text{Unit} = \frac{\text{moles}}{(\text{area})(\text{time})}$$

11. What is Knudsen diffusion and give the criterion for its occurrence? (NOV/DEC 2010)

Knudsen diffusion occurs in porous solids when the pore diameter, d to mean free path of the gas molecules is less than 0.2 ($d/\lambda < 0.2$).

12. How does mass transfer coefficient vary with D_{AB} in film theory and penetration theory? (NOV/DEC 2010)

In film theory, mass transfer coefficient is proportional to D_{AB} : $[K_C \propto D_{AB}]$

In penetration theory, mass transfer coefficient is proportional to $D_{AB}^{0.5}$: $[K_C \propto D_{AB}^{0.5}]$

13. What is the physical basis for mass transfer to occur? (NOV/DEC 2009)

- Mass Transfer phenomena arise from the distribution of sample molecules within either the stationary phase or mobile phase.
- Diffusion forms the basis for several mass transfer operations.

14. State the assumptions made in Chilton – Colburn analogy. (MAY/JUNE 2009)

Assumptions:

- Only a turbulent core is present.
- Velocity, temperature and concentration profiles are same.
- Schmidt number and Prandtl number are not equal to unity. $[N_{Pr} = N_{Sc} \neq 1]$

15. Differences between two fluxes J_A and N_A . (NOV/DEC 2007)

1. J_A is the diffusion co efficient and it is defined as the ratio of Flux to its concentration gradient. 2. It is given by $J_A = -D_{AB} \frac{cdxA}{dz}$ D_{AB}- diffusion coefficient $CDxA/dz$- conc. gradient	1. N_A is the mass flux and N_A of the given species is a vector quantity denoting the amount of the particular species in either mass or molar units, that passes per given increment of time through a unit area normal to the vector. 2. It is given by $N_A = C_A \gamma A$
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16. State the assumptions of Reynold's Analogy. (NOV/DEC 2007)

- Only turbulent core is present
- Velocity, temperature and concentration profilers are perfectly matching
- All diffusivities are same

17. Explain Molecular flux. (MAY/JUNE 2007)

Molar flux:

- It is defined as the rate of mass transfer across a unit area i.e.; the area being measured in the direction normal to the diffusion.

$$Unit = \frac{\text{moles}}{(\text{area})(\text{time})}$$

18. Explain diffusivity. (MAY/JUNE 2007)

Diffusivity:

- Diffusivity of a solute is defined as the rate of transfer of the solute in a given fluid under the driving force of a concentration gradient.
- It can also be defined as the mass of solute transferred per unit area per unit concentration gradient.

$$Unit = \frac{Area}{time}$$

- Diffusivity of solute decreases with its molecular weight

19. Explain when molecular diffusion occurs in solids. (MAY/JUNE 2007)

Molecular diffusion occurs in a solid if mobile particles are distributed non-uniformly in a medium, the random walk process tends to make the concentration everywhere uniform or, on a macroscopic scale, the mobile species exhibit a net flow from regions of high concentration to regions of low concentration.

20. Explain when Knudsen diffusion occurs in solids. (MAY/JUNE 2007)

Knudsen diffusion occurs when molecules frequently collide with the pore wall in a long pore with a narrow diameter (2.50 nm).

21. Define mass transfer coefficient. How mass transfer coefficient and diffusivity are related in film theory? (NOV/DEC 2006)

Mass transfer coefficient is defined as the ratio of rate of mass transfer per unit area to its concentration gradient.

It can also be defined as ratio of flux to its concentration gradient.

Mass transfer coefficient, MTC = flux/concentration gradient

$$MTC = \frac{Flux}{Conc. Gradient}$$

22. Define mass flux. (NOV/DEC 2005)

The mass (or molar) flux of a given species is a vector quantity denoting the amount of the particular species, in either mass or molar units, that passes per given increment of time through a unit area normal to the vector. The flux of species defined with reference to fixed spatial coordinates is

$$N_A = C A \gamma_A$$

23. How do you obtain overall mass transfer coefficient from individual mass transfer coefficients? (NOV/DEC 2005)

$$1/k_y = 1/k_y + m'/k_x$$

Where k_y and k_x are the locally applicable coefficients (individual mass transfer coefficient); and m' is the slope.

The above equation shows the relationship between the individual phase transfer coefficients and overall coefficient (k_y)

Similarly, $1/k_x = 1/m''k_y + 1/k_x$

Thus from the above two equations, the overall mass transfer coefficients can be obtained from individual mass transfer coefficients.

24. How the diffusivity of a multicomponent mixture can be estimated using the binary diffusivity values if all but one component is stagnant? (NOV/DEC 2004)

The expressions for diffusion in multicomponent systems become very complicated, but they can frequently be handled by using an effective diffusivity.

$$N_A = \frac{D_{A,m} P_t}{ZRT} \left(\frac{\overline{p_{A1}} - \overline{p_{A2}}}{P_{B,M}} \right)$$

$$D_{A,m} = \frac{1}{\left(\frac{y'_B}{D_{AB}} + \frac{y'_C}{D_{AC}} \right)}$$

25. Define film theory. (NOV/DEC 2004)

Film theory:

Film theory postulates that the concentration will follow the broken curve of fig. such that the entire concentration difference ($C_{A1}-C_{A2}$) is attributed to molecular diffusion within an effective film of thickness Z_F .

26. Define surface renewal theory. (NOV/DEC 2004)

Surface renewal theory:

The time of exposure of all eddies is not constant. So, it accounts for varying lengths of time of exposure.

27. What is an interstitial mechanism in the diffusion of solids?

Interstitial sites are placed between the atoms of a crystal lattice small diffusing solute forms may pass from an intestinal site to the next when the matrix atoms of the crystal lattice move aspect temporarily to provide the necessary space.

28. Define Stanton number.

Stanton number is a dimensionless number that measures the ratio of heat transferred into a fluid to the thermal capacity of fluid. It is used to characterize heat transfer in forced convection flows.

29. Define Sherwood number.

Sherwood number is a dimensionless number used in mass transfer operation. It represents the ratio of convective to diffusive mass transport.

30. Define Reynolds number.

Reynolds number is defined as the ratio of inertial force to viscous force.

PART B

1. Derive from the first principle the general rate equation for the steady state unidirectional molecular diffusion in gases at rest and in laminar flow for the following cases.

(i) For diffusion of A through non-diffusing B.

(ii) For equimolar counter diffusion. (Nov/Dec 2016)

(Or) Derive an expression for Steady state diffusion of A through non diffusing B and equimolar counter diffusion. (Nov/Dec 2016, 2011,14, May 2013)
[Treybal, Mass Transfer Operations,Page.No.26-29]

2. Oxygen (A) is diffusing through carbon monoxide (B) under steady state conditions, with equimolar counter current diffusion. The total pressure is $1 \times 10^5 \text{ N/m}^2$, and the temperature 0°C . The partial pressure of oxygen at two planes 2.0 mm apart is, respectively, 13000 and 6500 N/m^2 . The diffusivity for the mixture is $1.87 \times 10^{-5} \text{ m}^2/\text{s}$.

- Calculate the rate of diffusion of oxygen in Kmol/s through each square meter of the two planes. (Nov/Dec 2016) [Treybal, Mass Transfer Operations,Page.No.30]
3. Explain the theories used to determine the mass transfer coefficient. (Nov 2012, 13, 14) [Treybal, Mass Transfer Operations,Page.No.59-64]
4. Discuss the concept of individual and overall mass transfer coefficient. (Nov 2012, 13, 14, May 2013) [Treybal, Mass Transfer Operations,Page.No.106-114]
5. Ammonia is diffusing through a stagnant mixture consisting of one third Nitrogen and two-thirds Hydrogen by volume. The total pressure is 1 atm and the temperature is 200oc. calculate the rate of diffusion of ammonia through a film of gas 0.5mm thick, when ammonia concentration changes across the film is 12% and 7% by volume. The diffusivities at 200oc and 1 atm pressure are $D_{AB} = 5.391 \times 10^{-5} \text{ m}^2/\text{s}$ and $D_{BC} = 1.737 \times 10^{-4} \text{ m}^2/\text{s}$ (Nov 2012,13)

Solution: Steady state diffusion of A through non diffusing B

Given Data: $P_t = 1 \text{ atm} = 1.013 \times 10^5 \text{ N/m}^2$, $T = 200^\circ\text{C} = 473 \text{ K}$, $z = 0.5 \text{ mm} = 0.0005\text{m}$,

$R = 8.314 \text{ KJ/ Kmol K} = 8314 \text{ Nm/Kmol K}$

$y_{A1} = 12 \%$, $y_{A2} = 7 \%$, $y_B = 1/3 = 0.333$, $y_C = 2/3 = 0.667$

$$N_A = \frac{D_{AM} P_t}{zRT} \ln \frac{(1 - y_{A2})}{(1 - y_{A1})}$$

$$y'_B = \frac{1/3}{\frac{1}{3} + \frac{2}{3}} = 0.333, y'_C = \frac{2/3}{\frac{1}{3} + \frac{2}{3}} = 0.667$$

$$D_{AM} = \frac{1}{\sum_{i,B} \frac{y_i}{D_{A,i}}} = \frac{1}{\frac{y_B}{D_{A,B}} + \frac{y_C}{D_{A,C}}} = \frac{1}{\frac{0.333}{5.391 \times 10^{-5}} + \frac{0.667}{1.737 \times 10^{-4}}} = 9.98 \times 10^{-5} \text{ m}^2/\text{s}$$

$$N_A = \frac{D_{AM} P_t}{zRT} \ln \frac{(1 - y_{A2})}{(1 - y_{A1})} = \frac{(9.98 \times 10^{-5})(1.013 \times 10^5)}{0.0005 \times 8314 \times 473} \ln \frac{(1 - 0.07)}{(1 - 0.12)} = 2.84 \times 10^{-4} \text{ kmol/m}^2\text{s}$$

6. Methane diffuses at steady state through a tube containing helium. At point 1 the partial pressure of methane is P_{A1} is 15.55 kPa and at point 2, which is 30 mm apart , the partial pressure of methane is 10 kPa. The total pressure is 101.32 kPa and the temperature is 293 K. At this pressure and temperature the diffusivity is $6.75 \times 10^{-5} \text{ m}^2/\text{s}$. Calculate the flux of methane at steady state for equimolar counter diffusion and the partial pressure at 2 cm from point 1. (May 2010,Nov 2011)

Solution: For steady state equimolar counter diffusion, molar flux is given by

$$N_A = \frac{D_{AB}}{RTz} (p_{A1} - p_{A2}) \dots\dots(1)$$

Therefore,

$$N_A = \frac{6.75 \times 10^{-5}}{8.314 \times 298 \times 0.03} (55 - 15) \frac{\text{kmol}}{\text{m}^2 \cdot \text{sec}} = 3.633 \times 10^{-5} \frac{\text{kmol}}{\text{m}^2 \cdot \text{sec}}$$

And from (1), partial pressure at 0.02 m from point 1 is calculated as follows:

$$3.633 \times 10^{-5} = \frac{6.75 \times 10^{-5}}{8.314 \times 298 \times 0.02} (55 - p_A)$$

$$p_A = 28.33 \text{ kPa}$$

PART - C

1. A thin film 0.4 cm thick of an ethanol-water solution is in contact at 20°C at one surface with an organic liquid in which water is insoluble. The concentration of ethanol at the interface is 6.8 wt% and at the other side of film 10.8 wt%. The densities are 988.1 kg/m³ and 972.8 kg/m³ respectively for 6.8 wt% and 10.8 wt% ethanol solutions. Diffusivity of ethanol is 7.4 m²/s. Calculate the steady state flux in kmol/m²s. (NOV/DEC 2006) [Treybal, Mass Transfer Operations, Page.No.43-44]
2. (i) Explain Higbie's penetration theory. (NOV/DEC 2013) [Treybal, Mass Transfer Operations, Page.No.60-61]

(ii) Explain Reynolds analogy. (NOV/DEC 2013) [Treybal, Mass Transfer Operations, Page.No.64-66]
3. (i) Explain briefly the Analogies and their usefulness in mass transfer studies. (NOV/DEC 2010) [Treybal, Mass Transfer Operations, Page No.66-70]
(ii) How are mass transfer operations, classified? (NOV/DEC 2010) [Treybal, Mass Transfer Operations, Page No.2-5]

UNIT II GAS LIQUID OPERATIONS PART A

1. Define gas absorption. (NOV/DEC 2016)

Gas operation is an operation in which a gas mixture is contacted with a liquid for the purposes of dissolving one or more components of the gas and to provide a solution of them in the liquid.

2. Give two examples for gas absorption? (NOV/DEC 2016)

- (i) The gas from by-product coke ovens is washed with water to remove ammonia and again with an oil to remove benzene and toluene vapors.
- (ii) Hydrogen sulfide is removed from naturally occurring hydrocarbon gases by washing with various alkaline solutions in which it is absorbed.

3. Define HTU. (APR/MAY 2015)(MAY/JUNE 2007)(NOV/DEC 2006)

HTU:

- ✓ The height of a transfer unit (HTU) is a measure of the separation effectiveness of the particular packing for a particular separation process.
- ✓ The more efficient the mass transfer (i.e. large mass transfer coefficient), the small the value of HTU.

4. Define NTU. (APR/MAY 2015)(MAY/JUNE 2007)(NOV/DEC 2006)

NTU:

- ✓ The number of transfer units (NTU) required is a measure of the difficulty of the separation.
- ✓ A single transfer unit gives the change of composition of one of the phase equal to the average driving force producing the change.
- ✓ The NTU is similar to the number of theoretical trays required for trayed column.
- ✓ A large number of transfer units will be required for a very high product.
 - Height of packed towers = HTU * NTU

5. Write a note on pressure drop in packed towers for absorption. (APR/MAY 2015)

In determining the column diameter, we need to know what is the limiting (maximum) gas velocity that can be used. This is because the higher the gas velocity, the greater the resistance that will be encountered by the down-flowing liquid and the higher the pressure drop across the packings.

6. Write a note on flooding in packed towers for absorption. (APR/MAY 2015)

Too high a gas velocity will lead to a condition known as flooding whereby the liquid filled the entire column and the operation became difficult to carry out. High pressure will crush and damage the pickings in the column.

7. Define absorption factor.(NOV/DEC 2014,2013,2011)(APR/MAY 2010)(MAY/JUNE 2007)

The absorption factor $A = \frac{L}{mG}$ is the ratio of the slope of the operating line to that of the equilibrium curve.

8. Give the significance of absorption factor. (NOV/DEC 2014,2013,2011)(APR/MAY 2010)(MAY/JUNE 2007)

Significance:

- For values of A less than unity, fractional absorption of solute is limited even for infinite theoretical plate.
 - For values of A greater than unity, any degree of absorption is possible if sufficient trays are provided.
 - The value of A lies between 1.5 – 2
9. What are the characteristics features of tower packing? (NOV/DEC 2014)
- (i) Low pressure drop compared to tray column which results in a reduced base pressure/temperature, lower rates of degradation, lower levels of heat source and enhanced relative velocity.
 - (ii) Capacity of a properly selected and packed column is greater than tray column.
 - (iii) Liquid hold up in packed tower would be 2-3% maximum as compared to about 10-12% of a tray tower.
10. State four characteristics of solvents used in absorption operation. (NOV/DEC 2013)
- (i) Gas solubility
 - (ii) Volatility
 - (iii) Corrosiveness
 - (iv) viscosity
11. What is the significance of an operating line? (MAY/JUNE 2013)
- Operating line is a straight line, which indicates the relationship between gas and liquid concentration at any level in the tower.
- In the absorber, the operating line always lies above the equilibrium solubility curve.
- In the stripper, the operating line lies below the equilibrium solubility curve.
12. What is Lewis number?(NOV/DEC 2011)
- Lewis number is defined as the ratio of thermal diffusivity to the molecular diffusivity.
13. Define loading point. (NOV/DEC 2012)
- The point at which the liquid hold up starts to increase as indicated by a change in slope of the pressure drop – gas flow rate relationship is called the loading point.
14. What is meant by channeling? (NOV/DEC 2012)
- As liquid flows down over the packing as thin film, the films tend to grow thicker in some places and thinner in others and liquid collects into small rivulets and flows along some localized paths.
- At low liquid rates much of the packing surface may be dry or at most covered by a stagnant film of liquid. This effect is known as channeling.
15. Explain gas film controls the mass transfer. (APR/MAY 2010)
- Equation for overall mass transfer coefficient in gas phase is given as

$$\frac{1}{K_y} = \frac{1}{k_y} + \frac{m}{k_x}$$

The term $1/K_y$ is the resistance to mass transfer in gas films.

If $\frac{1}{k_y} \gg \frac{m}{k_x}$, $K_y \approx k_y$.

This controls the mass transfer. Eg: NH_3 & HCl adsorbed by water.

16. What is the difference between absorption and desorption? (NOV/DEC 2009)

Absorption	Desorption
*Absorption is an operation in which a gas mixture is contacted with a liquid for the purpose of preferentially dissolving one or more components of gas and to provide a solution of them in liquid.	*When mass transfer occurs in opposite directions to that of absorption i.e., from liquid to gas the operation, it is called desorption or stripping.
*Ex:- the gas from byproduct ovens is washed with water to remove benzene and toluene vapours	*These operations are used for solute recovery and solute removal

17. What is dispersion? (NOV/DEC 2009)

Dispersion is a system in which particles are dispersed in a continuous phase of a different composition or state. Dispersion is classified as suspension, colloid, solution.

18. What is coalescence? (NOV/DEC 2009)

Coalescence:

Coalescence is a process in which two phase domains of the same composition come together and form a larger phase domain.

19. What is flooding? (MAY/JUNE 2009)

Velocity of gas is increased the pressure drop increases rapidly and pressure drop-gas flow rate relationship becomes almost vertical. At some portions of the column, the liquid becomes the continuous phase and the flooding point is said to be reached, and the accumulation of liquid is rapid and the entire column may be filled with liquid, while a bed is being operated, the gas velocity must be lesser than the flooding velocity and as flooding is approached, most of the packing surface is wetted, maximizing the gas liquid contact area.

20. What is Murphee efficiency? (MAY/JUNE 2009)

It is the efficiency of any single plate based on the vapour phase composition.

The Murphee efficiency of the entire tray is,

$$E_{MG} = \frac{y_n - y_{n+1}}{y_n^* - y_{n+1}}$$

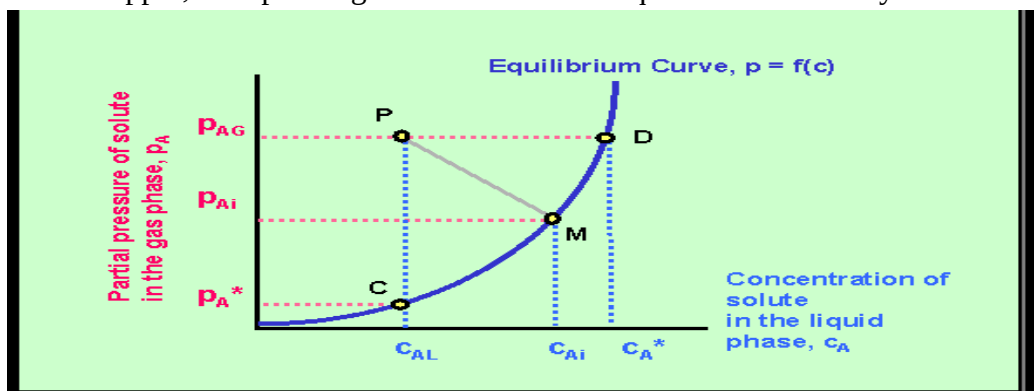
Where y_n^* - is the value in equilibrium with the leaving liquid of concentration x_n

y_n - average composition of the vapour leaving plate

y_{n+1} - average composition of the vapour entering plate.

21. What is meant by operating line? (NOV/DEC 2008)

- Operating line is a straight line, which indicates the relationship between gas and liquid concentration at any level in the tower.
- In the absorber, the operating lines always lies above the equilibrium solubility curve.
- In the stripper, the operating line lies below the equilibrium solubility curve.



22. Define stage efficiency. (NOV/DEC 2008)

Stage efficiency is defined as the fractional approach to the equilibrium which a real stage produces.

It is the ratio of actual solute transfer to that if equilibrium were obtained.

The most frequently used expression is the murphee stage efficiency, the fractional approach of one leaving steam to equilibrium with the actual concentration in the other leaving steam.

$$E_{ME} = \frac{Y_2 - Y_1}{Y_2^* - Y_1}$$

$$E_{MR} = \frac{X_1 - X_2}{X_1 - X_2^*}$$

23. State Kremser-Brown- Souder's equation. (NOV/DEC 2007)

The equation has been the tool for obtaining the maximum allowable vapor velocity in vapor-liquid separation vessels (variously called flash drums, knockout drums, knockout pots, compressor suction drums and compressor inlet drums). It has also been used for the same purpose in designing trayed fractionating columns, trayed absorption columns and other vapor-liquid contacting columns.

24. Write the significance of Kremser-Brown- Souder's equation. (NOV/DEC 2007)

A vapor-liquid separator drum is a vertical vessel into which a liquid and vapor mixture (or a flashing liquid) is fed and wherein the liquid is separated by gravity, falls to the bottom of the vessel, and is withdrawn. The vapor travels upward at a design velocity which minimizes the entrainment of any liquid droplets in the vapor as it exits the top of the vessel.

$$V = (k) \sqrt{\frac{\rho_L - \rho_V}{\rho_V}}$$

where:

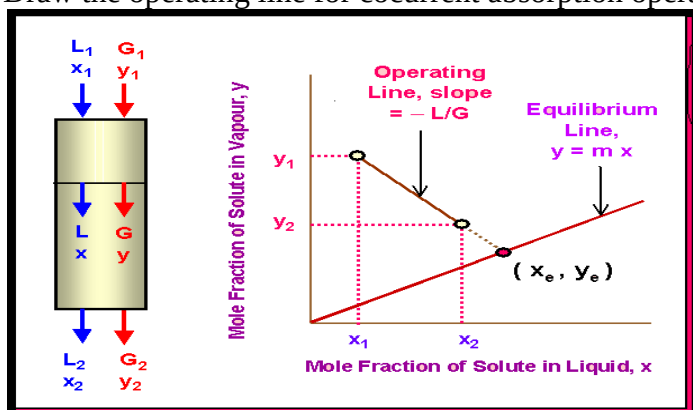
V = maximum allowable vapor velocity, m/s

ρ_L = liquid density, kg/m³

ρ_V = vapor density, kg/m³

k = 0.107 m/s (when the drum includes a de-entraining mesh pad)

25. Draw the operating line for cocurrent absorption operation. (NOV/DEC 2007)



26. What is meant by weeping?

Weeping is when liquid flows downward through the holes in a distillation tray, normally vapour rises up through the holes and contacts the liquid on the tray. If the vapour rate is too low the liquid may be able to drop to the next stage through the holes, resulting in less than optimal vapour/liquid contact (and therefore less than optimal separation). Condensed liquid from above trays is generally distributed onto a distillation tray via a weir.

27. Define stripping.

Stripping is an inverse operations performed when it is desired to transfer a volatile component from a liquid into a gas.

28. Explain sieve trays.

Sieve trays are simply metal plates with holes in them. Vapour passes straight upward through the liquid on the plate. The arrangement, number and size of the holes are design parameters.

29. Define bubble cap trays.

A bubble cap tray has riser or chimney fitted over each hole, and a cap that covers the riser. The cap is mounted so that there is a space between riser and cap to allow the passage of vapour. Vapour rises through the chimney and is directed downward by the cap, finally discharging through slots in the cap, and finally bubbling through the liquid on the tray.

30. When will be the operating line and equilibrium curve will be straight for an absorber?

In an absorber, both equilibrium curve and operating line will be straight for dilute solution and non isothermal operation.

31. Define stripping factor.

It is defined as the ratio of slope of equilibrium curve to the slope of operating line.

It is a reciprocal of absorption factor.

$$S = 1/A$$

PART B

1. An air-ammonia mixture containing 5% ammonia by volume is absorbed in water in a packed column operated at 20°C and 1 atm pressure. So as to recover 98% NH₃. If the inert gas flow rate in the column is 1200 kg/m².hr. calculate
 - (i) The minimum mass velocity of water from this column.
 - (ii) The number of transfer units in the column taking the operating liquid rate to be 1.25 times the minimum.
 - (iii) The height of the packed tower taking the overall transfer coefficient $K_G a$ to be 128 kg moles/ m³.hr.atm. The relationship for equilibrium in the column is $y = 1.154 x$, where y and x are in mole fraction units. (NOV/DEC 2016) [Treybal, Mass Transfer Operations, Page.No.337]
2. Derive an equation for finding out the height of a packed column operating in a counter current method. (NOV/DEC 2016) (or) Obtain an expression for the determination of the height of the absorption tower. (Nov 2013, 14) [Treybal, Page.No.301-304]
3. A gas from a petroleum distillation column has its concentration of H₂S reduced from 0.03 kgmole H₂S / kgmoles inert gas to 1 % of its value by scrubbing with a tri ethanol amine with water as a solvent in a counter current tower of height 7.79 m operating at 300°C and 1 atm. The equilibrium relation is $Y = 2 X$. Pure solvent enters the tower and leaves containing 0.013 kg mole H₂ S / kgmole of solvent. If the flow of inert hydrocarbon gas is 0.015 kgmole/ m²S and the gas phase controls the mass transfer. Calculate the overall coefficient for absorption. (Nov 2013)

Solution:

Given Data: $Y_1 = 0.03$, $Y_2 = 0.0003$, $T = 573$ K, $P_t = 1$ atm, $X_2 = 0$, $X_1 = 0.013$, Inert Gas $G_s = 0.015$ kmol/m²s, Height of the tower = 7.79m

Equilibrium relation is $Y = 2 X$, $Y_{e1} = 2X_{e1} = 2*(0.013) = 0.026$

$$NTU = \frac{\frac{Y_1 - Y_2}{(Y_1 - Y_{e1}) - (Y_2 - Y_{e2})}}{\ln \left(\frac{Y_1 - Y_{e1}}{Y_2 - Y_{e2}} \right)} = \frac{\frac{(0.03 - 0.0003)}{(0.03 - 0.026) - (0.0003 - 0)}}{\ln \frac{(0.03 - 0.026)}{(0.0003 - 0)}} = 20.79$$

Height of the tower = HTU x NTU

$$\therefore HTU = \frac{\text{Height of the tower}}{NTU} = \frac{7.79}{20.79} = 0.374 \text{ m}$$

$$HTU = \frac{G_s}{K_G a P_t} = \frac{0.015}{K_G a (1)}, \therefore K_G a = \frac{0.015}{HTU} = \frac{0.015}{0.374} = 0.04 \text{ kmol/atm.m}^3\text{s}$$

The overall coefficient for absorption $K_G a = 0.04 \text{ kmol/atm.m}^3\text{s}$

4. Explain in detail about choice of solvent used for absorption and absorption with chemical reaction. (Nov 2012, May 2013)[Treybal, Page.No.281-282,333]
5. Distinguish Plate and Packed towers. Explain Flooding and loading in packed towers. (May 2010, 13, Nov 2009) [Treybal, Page.No.194-195]
6. It is desired to recover 98% ammonia from air-ammonia mixture containing 2% ammonia at 20 C and at 1 atm by scrubbing with water in a tower packed with 2.54 cm rasching rings. If the gas flow rate is $19.5 \text{ kg/m}^2 \cdot \text{min}$ at the inlet and liquid flow rate is 1.8 times the minimum. Estimate the height of packed tower for countercurrent operation. Absorption is assumed to be isothermal. The equilibrium relation is given by $y = 0.764 x$, where y, x are gas and liquid phase composition of ammonia in mole fraction respectively. The overall mass transfer coefficient is $1.04 \text{ kg mole/m}^3 \text{ atm} \cdot \text{min}$ [Treybal, Page.No.339]

PART - C

1. (i) Derive an operating line equation for gas absorber and stripper section of counter current tower.(NOV/DEC 2015) [Treybal, Mass Transfer Operations, Page No.282-285]
 (ii) List out the essential properties for a good tower packing used in gas liquid contact operation. (NOV/DEC 2015) [Treybal, Mass Transfer Operations, Page No.281-282]
 2. Explain in detail about the mass transfer theories in packed tower absorption process highlighting the effect of pressure. (NOV/DEC 2015) [Treybal, Mass Transfer Operations, Page No.277-279]
 3. NH_3 is absorbed from a gas by water in a scrubber under atm pressure. The initial NH_3 content in the gas is $0.04 \text{ kmole / kmole}$ of inert gas. The recovery of NH_3 by absorption is 90%. The water enters the tower free from NH_3 . Estimate the
 - (i) Concentration of NH_3 in the existing liquid if the actual water used is 1.5 times minimum.
 - (ii) Number of theoretical stages required If the height of a transfer unit is 0.5 m estimate the height of column.
- x : 0.005 0.01 0.0125 0.015 0.02 0.023
 y : 0.0045 0.0102 0.0138 0.0183 0.0273 0.0327
 Where x and y are mole ratios. (MAY/JUNE 2013) [Treybal, Mass Transfer Operations,Page.No.340]

UNIT III VAPOUR LIQUID OPERATIONS

PART A

1. What is “Relative volatility”? Give expression for a binary mixture.(NOV/DEC 2016,2013,2008,2005)(APR/MAY 2010)(MAY/JUNE 2009)

It is the ratio of the vapor pressure of ‘A’ to the vapor pressure of ‘B’ at the same temperature.

$$\alpha = \frac{(1-x)y^*}{(1-y^*)x} \quad \alpha = \frac{P_A}{P_B}$$

2. Define total reflux. (NOV/DEC 2016)

The entire area between the equilibrium curve and diagonal line is used for separation, with the largest possible driving force. This condition of infinite reflux ratio is known as the total reflux, and for a specified separation (i.e. fixed x_D and x_B), the number of theoretical stages required is a minimum. In practice, the total reflux can be achieved by reducing the feed to zero, returning all the overhead product back to the column as reflux and reboiling the entire bottom product.

3. Write the limitations of McCabe Thiele method. (APR/MAY 2015)

One of the main disadvantages of the McCabe-Thiele Method is that it is not very useful for analyzing the distillation of mixtures containing more than 2 components.

Advantages:

- Less rigorous, enthalpy data not required.
- Adequate for many applications, more commonly use because of its simplicity
- Uses graphical solution for binary mixture on equilibrium diagram (x-y plot).
- Provides the number of theoretical (ideal) trays required for a given separation.
- Pressure is assumed constant throughout the entire column

4. Define optimum reflux ratio. (NOV/DEC 2014)

Optimum reflux ratio is that at which the total cost of the distillation is a minimum, taking into account the capital cost of the column (which depends on the number of theoretical plates) and running cost, which depends on the reflux ratio. The total cost, which is the sum of fixed cost and operating cost, must therefore pass through a minimum. The reflux ratio at this minimum total cost is the optimum (or economical) reflux ratio.

5. Define and classify azeotropes. (NOV/DEC 2014)

- (i) Positive and negative azeotropes
- (ii) Heterogeneous and homogeneous azeotropes

6. Write the significance of relative volatility in distillation. (NOV/DEC 2013,2008,2005)(APR/MAY 2010)(MAY/JUNE 2009)

The values of α is the measure of separability. It ranges between 0 to 1.

If $\alpha = 1$, no separation is possible.

If $\alpha > 1$, the greater the degree of separation.

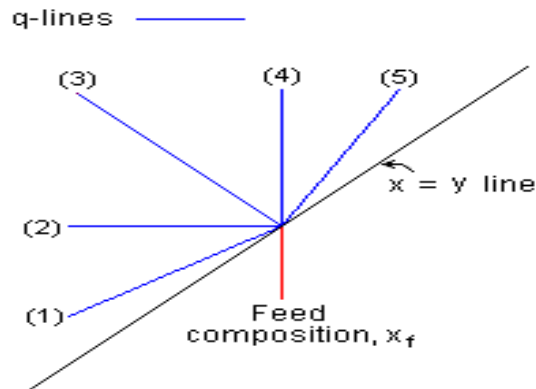
7. What is HETP. (NOV/DEC 2013,2012)

Height equivalent to theoretical plate.

This is the height of packing that will give the same separation as one theoretical plate. (ie) a section of packing of a height such that the vapour leaving the top of the section will have the same composition as the vapour in equilibrium with the liquid leaving the bottom of the section.

8. How is the slope of the feed line estimated?

The feed line is also called as the q -line. Location of the line for various feed condition is shown in the graph below:



Example q-line slopes:

- (1) Superheated vapor feed
- (2) Saturated vapor feed
- (3) Partially vaporized feed
- (4) Saturated liquid feed
- (5) Subcooled liquid feed

$$Y = q/q-1x - z_f/q-1$$

This, the locus of intersection of the q line is a straight line of slope $q/q-1$. thus the slope of feed line is estimated.

9. Define external reflux ratio. (MAY/JUNE 2013)

The molar ratio of reflux to withdrawn distillate is the external reflux ratio.

$$R = \frac{L}{D}$$

Where R – Reflux ratio

L – Reflux liquid

D – Distillate

10. Define internal reflux ratio. (MAY/JUNE 2013)

The ratio of L/G is called the internal reflux ratio.

$$R = \frac{L}{G}$$

Where R – Internal Reflux ratio

L – Liquid

G – Gas

11. State Rayleigh's equation. (MAY/JUNE 2013)

The Equation is: $\ln \frac{F}{W} = \int_{x_w}^{x_f} \frac{dx}{(y^*-x)}$

where , F= moles of charge of composition, x_f

W = moles of residual liquid of composition, x_w

This is the known as Rayleigh equation, named after Lord Rayleigh who first derived it.

12. State Raoult's law. (NOV/DEC 2012,2004)

The equilibrium partial pressure of a constituent/component in a solution at a given temperature is equal to the product of its vapour pressure in the pure state and its mole fraction in the liquid phase.

$$p_A = p_A^0 x_A$$

p_A - equilibrium partial pressure

p_A^0 - vapour pressure

x_A - mole fraction

13. Define minimum reflux ratio. (NOV/DEC 2011)

Minimum reflux ratio requires an infinite number of trays for the separation desired & it corresponds to the minimum reboiler heat load and condenser cooling load for the separation.

14. What is the difference between steam and flash distillation? (NOV/DEC 2011)

Steam distillation	Flash distillation
1. When a mixture of two practically immiscible liquids is heated while being agitated to expose the surfaces of both the liquids to the vapour phase, each constituent independently exerts its own vapour pressure as a function of temperature as if the other constituent were not present. 2. Consequently, the vapour pressure of the whole system increases.	1. Single stage operation where in a liquid mixture is partially vapourized, the vapour allowed to come to equilibrium with the residual liquid and resulting vapour and liquid phases separated. 2. Rayleigh's method is not applicable

15. In a binary mixture the vapor pressure of A is 800 mm Hg and that of B is 400 mm Hg. Estimate the vapor composition in equilibrium with the liquid if the composition in liquid phase is 50 mole % A. (NOV/DEC 2011)

Solution:

$$y_A = \frac{\alpha x_A}{1 + (\alpha - 1)x_A}$$

$$\alpha = \frac{p_A}{p_B} = 800/400 = 2$$

$$x_A = 0.5$$

$$y_A = \frac{2(0.5)}{1 + (2 - 1)0.5} = \frac{1}{1 + 0.5} = 0.667$$

$$y_A = \mathbf{0.667}$$

16. What is steam distillation? (NOV/DEC 2011)

Steam distillation:

When a mixture of two practically immiscible liquids is heated while being agitated to expose the surfaces of both the liquids to the vapour phase, each constituent independently exerts its own vapour pressure as a function of temperature as if the other constituent were not present. Consequently, the vapour pressure of the whole system increases.

17. Mention the application of steam distillation. (NOV/DEC 2011)

Applications:

- To separate high boiling substances from nonvolatile impurities.
- To remove high boiling volatile impurities from still higher boiling substances.
- Steam distillation is commonly used where the material to be distilled is thermally unstable.

18. What are the assumptions made in McCabe Thiele method? (APR/MAY 2010)

- (i) The liquid and vapour in each tray will be saturated.
- (ii) The molar flow rates of vapour, liquid are constant at all stages in rectifying section.
- (iii) Heats of solutions are neglected.
- (iv) The liquid is at the bubble point and vapour is at dew point.

19. What is dispersion? (NOV/DEC 2009)

Dispersion is a system in which particles are dispersed in a continuous phase of a different composition or state. Dispersion is classified as suspension, colloid, solution.

20. What is coalescence? (NOV/DEC 2009)

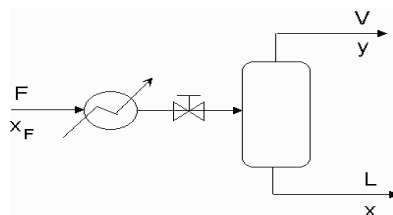
Coalescence:

Coalescence is a process in which two phase domains of the same composition come together and form a larger phase domain.

21. Briefly explain the principle of flash evaporation. (NOV/DEC 2009)

Flash vaporization or equilibrium distillation, are single stage operation wherein a liquid mixture is partially vaporized, the vapour allowed to come to equilibrium with the residual liquid and the resulting vapour and liquid phases are separated and removed from the apparatus.

Flash distillation (sometimes called "equilibrium distillation") is a single stage separation technique. A liquid mixture feed is pumped through a heater to raise the temperature and enthalpy of the mixture.



22. What are azeotropes? (MAY/JUNE 2009)

An azeotrope is a liquid mixture with an equilibrium vapour of the same composition as the liquid is the same as that of the liquid mixture.

23. Write the applications of steam distillation. (NOV/DEC 2008)

- To operate at a different total pressure in the presence of liquid water where the ratio of the vapour pressures of the substances may be more favorable
- To sparge superheated steam (or other insoluble gas) through the mixture in the absence of liquid water and to vaporize the ethyl aniline by allowing it to saturate the steam.

24. When the operating lines of stripping and rectifying sections coincide with diagonal in the McCabe Thiele method? (NOV/DEC 2007)

If the operating lines of stripping and rectifying sections coincide with diagonal in mccabe-thiele method then it is referred as total reflux. At the total reflux condition no product would be removed from the operation. All the overhead vapor is condensed and returned as reflux.

Consequently, the reflux ratio $1L/D$ infinite.

25. What is the temperature range of steam distillation? Why? (NOV/DEC 2007)

Steam distillation is a special type of distillation for temperature sensitive materials like natural aromatic compounds. For example, the boiling point of bromobenzene is 156 c and boiling point of water is 100 c, but a mixture of the two boils at 95 c. Thus, bromobenzene can be easily distilled at a temperature 61 c below normal boiling point.

26. Explain how azeotropic mixtures are separated? (MAY/JUNE 2007)

Azeotropic distillation is range of techniques used to break or separate an azeotrope in distillation.

It refers to the specific technique of adding another component to generate a new, lower boiling azeotrope that is heterogeneous (ex. producing two, immiscible liquid phases) such as with the addition of benzene to water and ethanol.

Eg: A common distillation with an azeotrope is the distillation of ethanol and water.

27. Explain the principle of steam distillation. (MAY/JUNE 2007)

When a mixture of two practically immiscible liquids is heated while being agitated to expose the surfaces of both the liquids to the vapour phase, each constituent independently exerts its own vapour pressure as a function of temperature as if the other constituent were not present. Consequently, the vapour pressure of the whole system increases.

28. The vapor pressures of A and B are 200 mm Hg and 400 mm Hg. The total pressure is 760 mm Hg. Estimate the relative volatility? (NOV/DEC 2006)

Solution:

$$x = \frac{P_t - P_B}{P_A - P_B}$$
$$x = \frac{760 - 400}{200 - 400} = -1.8$$

$$y^* = \frac{P_A x}{P_t}$$

$$y^* = \frac{400(-1.8)}{760} = -0.947$$

$$\alpha = \frac{y^*(1-x)}{x(1-y^*)} = 0.75$$

$$\alpha = 0.75$$

29. Define external reflux ratio. How is it related with internal reflux ratio? (NOV/DEC 2006)

The molar ratio of reflux to withdrawn distillate is the external reflux ratio.

$$R = \frac{L}{D}$$

Where R – Reflux ratio

L – Reflux liquid

D – Distillate

The ratio of L/G is called the internal reflux ratio.

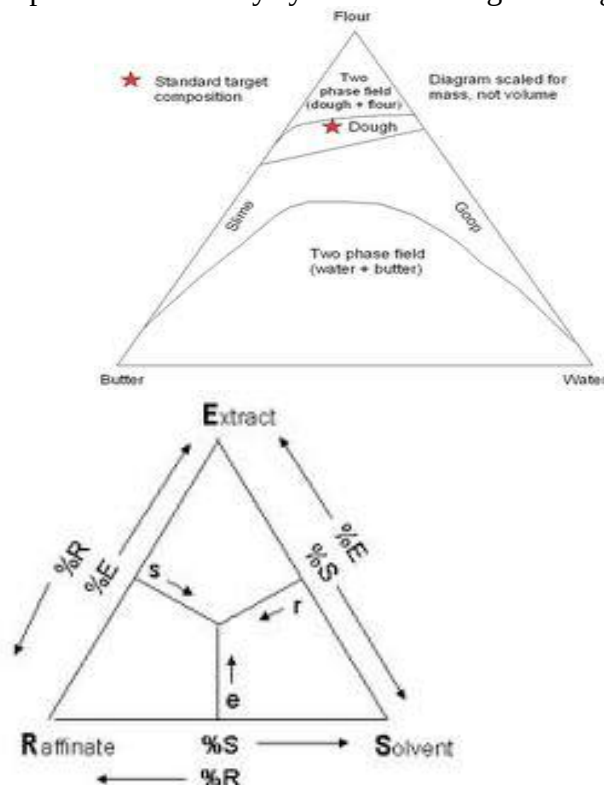
$$R = \frac{L}{G}$$

Where R – Internal Reflux ratio

L – Liquid

G – Gas

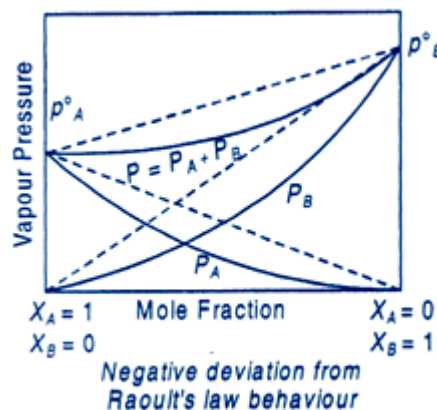
30. Represent the ternary system in a triangular diagram. (NOV/DEC 2005)



The above two triangular diagrams represent ternary system and shows Liquid-Liquid equilibrium.

31. What is meant by negative deviation from ideality? (NOV/DEC 2004)

A binary solution will have components A and B. If the force of attraction between molecular of and A and B in the solution are stronger than that of between A — A and B — B, then the tendency of escaping of molecules A—B from the solution becomes less than that of pure liquids. The total pressure of the solution will be lower than the corresponding vapour pressure of ideal solution of the same component A and B. This type of solution shows negative deviation from Raoult's law. The negative deviation of solution have been shown in figure. Some energy released when we mix both solutions. This reaction is exothermic reaction. For Exothermic reaction ΔH is always negative



PART B

1. What is flash distillation and explain. (NOV/DEC 2016, 2012) [Treybal, Mass Transfer Operations, Page.No.363-365]
2. Explain the process of Azeotropic distillation. (NOV/DEC 2016,2014) [Treybal, Mass Transfer Operations, Page.No.455-457]
3. Explain the procedure to determine the minimum number of theoretical plates by Ponchon Savarit method and McCabe Thiele method. (APR/MAY 2015) (Nov 2011, 12, 13) [Treybal, Mass Transfer Operations, Page.No.402-412]
4. A feed mixture of A and B (45 mole %A and 55 mol % B) is to be separated into a top product containing 96 mol %A and bottom product having 95 mol % B. The feed is 50% vapour and reflux ratio is 1.5 times the minimum. Determine the number of ideal trays required and the location of feed tray. Given $\alpha_{AB} = 2.8$. (Nov 2012, 2013)

Solution :

Basis : 100 Kgmol of the feed

Overall Material Balance: (Mole %)

$$F = B + D; 100 = B + D$$

$$\text{Balance on A: } Fx_F = Bx_B + Dx_D$$

$$100(0.45) = B(0.05) + D(0.96) = (100-D)(0.05) + D(0.96)$$

D = 44 kg moles - molal flow rate of the distillate

B = 56 kgmoles - molal flow rate of the residue

- 1) No. of theoretical plates

$$x_F = 0.45, x_D = 0.96, x_B = 0.05$$

From graph, $\frac{x_D}{R_m+1} = 0.38, \therefore R_m = 1.526$

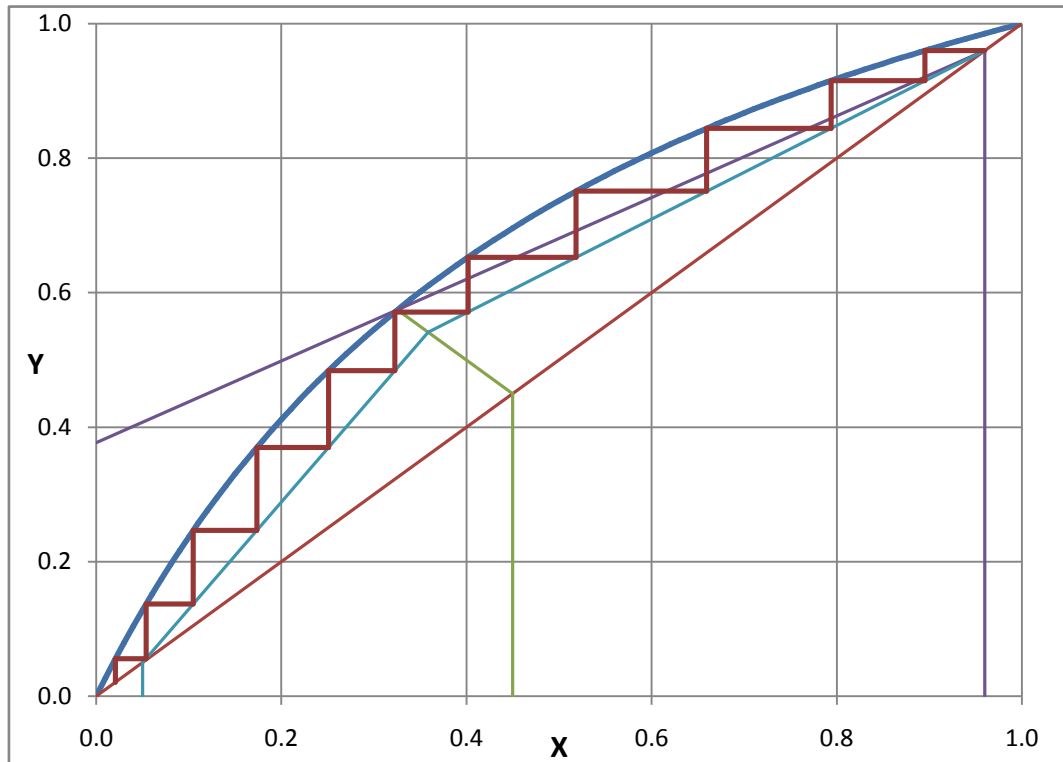
$$R = 1.5 * R_m = 1.5 * 1.526 = 2.29$$

$$\text{Intercept on y-axis} = \frac{x_D}{R+1} = \frac{0.96}{2.29+1} = 0.29$$

Feed is 50 % vapour, therefore **q = 0.5**

$$\text{Slope of the q-line, } \tan \theta = \frac{-q}{1-q} = \frac{-0.5}{1-0.5} = -1, \therefore \theta = -45^\circ$$

$\therefore$ No. of theoretical plates by Mc Cabe thiele method is constructed as follows



No. of theoretical plates (including reboiler) = 11

Location of the feed tray = 6

5. A liquid mixture containing 50 mole % n- heptane and 50 mole % n-octane at 300C is to be continuously flash vaporized at 1 atm to vaporize 60 mole % of feed. Compute the composition of distillate and residue. Vapor pressure data at 1 standard atm is given below.

Tempo C	98.4	105	110	115	120	125.6
PA, mm Hg	760	940	1050	1200	1350	1540
PB, mm Hg	333	417	484	561	650	760

(Nov 2011, 2014) [Treybal, Page.No.370]

6. A continuous distillation column is to be designed 7000kg/hr of liquid mixture with 60% methanol and 40 mole% water into an overhead product containing 90 mole% methanol and water product 95 mole% water. Reflux ratio of 2 times the minimum value is used. Assume relative volatility of methanol and water is 3. Calculate (i) the moles of overhead of water product. (ii) Number of ideal trays and feed tray if the feed is at boiling point. (NOV/DEC 2007) [Treybal, Mass Transfer Operations, Page.No.470]

PART C

1. Explain the principle of steam distillation and its applications. (NOV/DEC 2013)(MAY/JUNE 2013) [Treybal, Mass Transfer Operations, Page.No.367-370]
2. A mixture of 40% A and 60% B is to be separated by distillation using a reflux ratio 3.5 so as to form an overhead product containing 95mol% of A and a bottom product containing 95mol% of B.. The feed is saturated vapour. The relative volatility of A to B is 2.5. Determine the following:
 - (i) Minimum reflux ratio
 - (ii) Number of theoretical plates
 - (iii) Minimum number of theoretical plates (MAY/JUNE 2013) [Class notes]
3. A liquid mixture containing 40 mole % n-heptane and 60 mole % n-octane is to be continuously flash vaporized at 1 atmospheric pressure to vaporize 50 mol% of the feed..What will be composition of the vapor and liquid that leaves the separator?
Data given: The relative volatility = 2.16 (NOV/DEC 2011) [Class notes]

UNIT IV EXTRACTION OPERATIONS PART A

1. Write the properties of a good solvent for extraction? (NOV/DEC 2016,2011)
 - (i) Selectivity
 - (ii) Distribution coefficient
 - (iii) Insolubility of solvent
 - (iv) Recoverability
 - (v) Density
 - (vi) Interfacial tension
 - (vii) Chemical reactivity
 - (viii) Viscosity, vapour pressure & freezing point.
 - (ix) It should be nontoxic, nonflammable and of low cost.
2. What is the principle of leaching? (NOV/DEC 2016)
 Leaching is the preferential solution of one or more constituents of a solid mixture by contact with a liquid solvent. Leaching referred to percolation of the liquid through a fixed bed of the solid.
3. Derive Kremser equation for the continuous counter-current extraction operation. (APR/MAY 2015)

The *Kremser Equation*, an "absorption factor method", provides an algebraic solution for analyzing equilibrium cascades. It cannot be used for every problem, but is convenient for several cases, notably:

- dilute gas absorption (when set up on "solvent free" basis)
- distillation (use for the extreme ends of a high purity separation where the curvature of the equilibrium curve is not significant)
- leaching

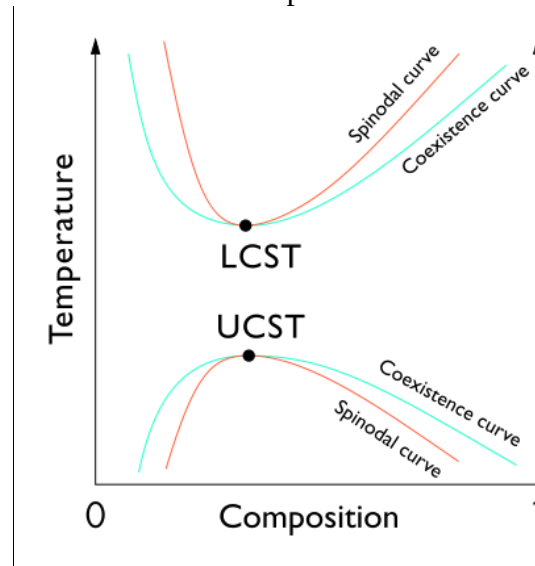
$$n = \frac{\text{LOG} \left[\left(\frac{x_f - y_s/m}{x_n - y_s/m} \right) \left(1 - \frac{1}{E} \right) + \frac{1}{E} \right]}{\text{LOG } E}$$

Where: n = Number of theoretical stages required
 x_f = Conc. of solute in feed on solute free basis
 x_n = Conc. of solute in raffinate on solute free basis
 y_s = Conc. of solute in solvent on solute free basis
 m = Distribution coefficient
 E = Extraction factor = $(m)(S/F)$

4. Write the importance of bimodal curve in phase diagram for a biphasic system. (APR/MAY 2015)

Bimodal curve, also known as the coexistence curve, denotes the condition at which two distinct phases may coexist. Equivalently, it is the boundary between the set of conditions in which it is thermodynamically favorable for the system to be fully mixed and the set of conditions in which it is thermodynamically favorable for it to phase separate.^[1] In general, the binodal is defined by the condition at which the chemical potential of all solution components is equal in each phase. The

extremum of a binodal curve in temperature coincides with the one of the spinodal curve and is known as a critical point.



5. What is heap leaching? (NOV/DEC 2014,2012)(APR/MAY 2010)
 Low grade ores whose mineral values do not warrant the expense of crushing or grinding can be leached in the form of run-of-mine lumps built into huge piles upon impervious ground the leach solution introduced into ponds in the top of heap, percolates down to the drain pipes at the base, where it is leached away. This is Heap Leaching.
6. What are the various factors which limits the rate of Solid-Liquid extraction? (NOV/DEC 2014)
 - (i) Primary properties – size distribution and shape of the particles and the surface properties of the particles in their solution environment.
 - (ii) State of the system – porosity or concentration, and the homogeneity and extent of dispersion of the particles.
 - (iii) Macroscopic properties – permeability or specific resistance of the filter bed or filter cake, the terminal settling velocity of the particles, or the bulk settling rate of the suspension.
7. State four metals separated from its ore by leaching operations. (NOV/DEC 2013)
 - (i) Copper
 - (ii) Gold
 - (iii) Cobalt
 - (iv) Manganese
 - (v) Nickel & zinc.
8. When do you prefer liquid- liquid extraction? (NOV/DEC 2013,2012)(APR/MAY 2010)
 - *In liquid-liquid extraction, the major constituents of the two phases are chemically different and this makes separations according to chemical type possible. So, this method is used for separations that are not possible by other methods like distillation.
 - *It can be used as a substitute for chemical methods, so that expensive disposal problems can be avoided
 - *This method can also be used to avoid thermal decomposition

9. What is a Decoction?(MAY/JUNE 2013)(NOV/DEC 2006)

Decoction refers specifically to the use of the solvent at its boiling temperature. When the soluble material is largely on the surface of an insoluble solid and is merely washed off by the solvent, the operation is sometimes called elution.

10. Define: Tie line. (MAY/JUNE 2013) (MAY/JUNE 2007)

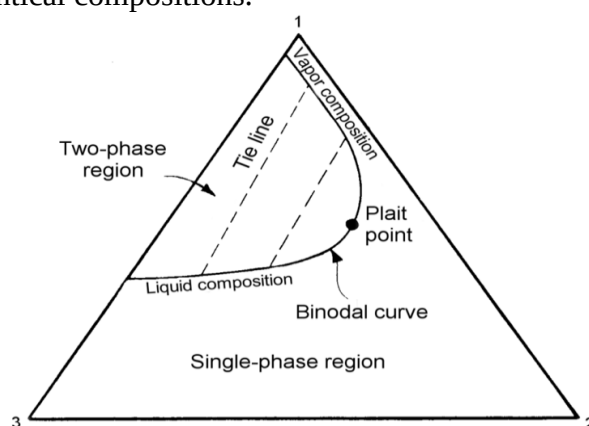
Tie line:

The line which show the compositions of the two phases that exist in equilibrium with each other at a particular temperature.

11. Define: plait point. (MAY/JUNE 2013) (MAY/JUNE 2007)

Plait point:

It is located near the top of the two-phase envelope, at the inflection point. It represents a condition where the 3-component mixture separates into two phases, but the phases have identical compositions.



12. State the difference between adsorption and extraction. (NOV/DEC 2011)

Adsorption	Extraction
1. Adsorption involves contact of solids with either liquids or gases and mass transfer in the direction fluid to solid. 2. In the field of gaseous separations, adsorption is used to dehumidify air and other gases	1. Separation of the constituents of a liquid solution by contact with another insoluble liquid. 2. A mixture of p- and o-nitrobenzoic acids can be separated by distributing them between the insoluble liquids chloroform and water.

13. What is a solutropic system? (NOV/DEC 2010)(MAY/JUNE 2007)

In the solubility diagrams for a number of ternary liquid systems, the slope of the tie lines changes in direction as the amount of solute increases. Such systems have been called "solutropic".

Solutrope : A ternary mixture with two liquid phases and a third component distributed between the phases, or selectively dissolved in one or the other of the phases; analogous to an azeotrope.

14. Define selectivity. (NOV/DEC 2010)

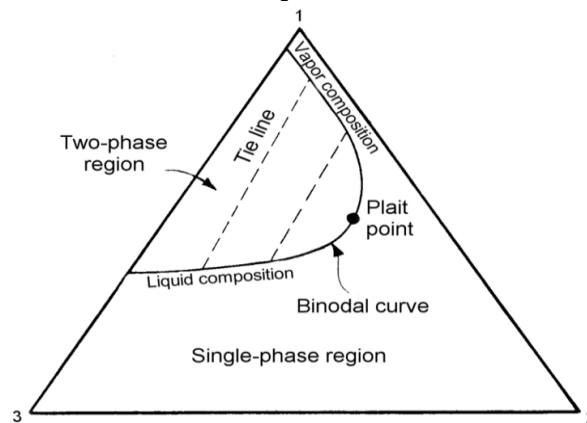
The effectiveness of solvent B for separating a solution of A and C into its components is measured by comparing the ratio of C to A in the B-rich phase to that in the A-rich phase at equilibrium. The ratio of these ratios is called separation factor (or) selectivity ' β '.

$$\text{Selectivity } \beta = \frac{(\text{Wt. fraction C in E})/(\text{Wt. fraction A in E})}{(\text{Wt. fraction C in R})/(\text{Wt. fraction A in R})}$$

E-Extract, R-Raffinate, C-Solute

15. What type of extractor is used in extracting radioactive materials? (NOV/DEC 2009)
Pulsed columns types of extractor are used in extracting radioactive materials from solutions.

16. What is plait point? (MAY/JUNE 2009) (NOV/DEC 2008,2004)
The plait point is located near the top of the two-phase envelope, at the inflection point. It represents a condition where the 3-component mixture separates into two phases, but the phases have identical compositions.



17. Give two examples for leaching operation. (MAY/JUNE 2009)
- (i) Sugar is leached from sugar beets with hot water.
 - (ii) Vegetable oils are recovered from seeds such as soybeans and cottonseed by leaching with organic solvents.
 - (iii) Tannin is dissolved out of various tree barks by leaching with water.
18. Write any two industrial applications of leaching. (NOV/DEC 2008)
- (i) Copper minerals are dissolved from their ores by leaching with sulfuric acid or ammoniacal solutions
 - (ii) Gold is separated from its ores with aid of sodium cyanide solutions.
19. With a sketch show the effect of temperature on Type –I extraction system. (NOV/DEC 2007)

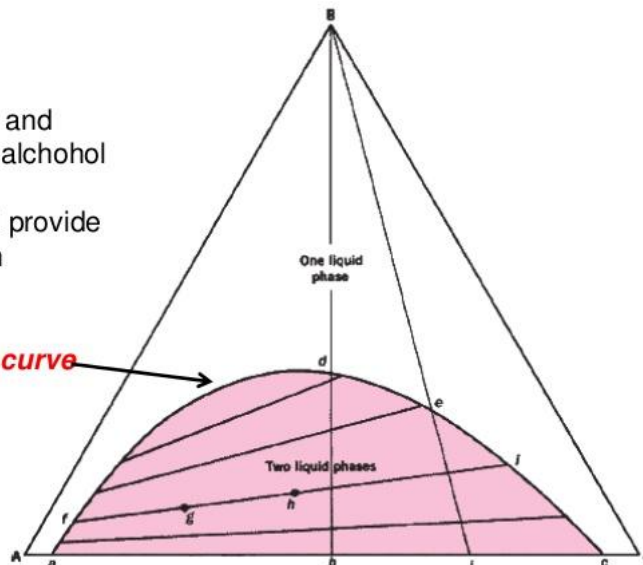
Ternary Systems with One Pair of Partially Miscible Liquids

e.g. Water and benzene + alcohol

- Alcohol provide solvation

- **binodal curve**

26



Changes in temperature will cause the area of immisibility (the binodal curve) to change

Area of binodal is decreases as the temperature is increased as miscibility is increased.

A point is reached at which complete miscibility is obtained and the binodal vanishes.

20. What is lixiviation? (NOV/DEC 2007)

Lixiviation is used less frequently as a Synonym for leaching although originally it referred specifically to the leaching of alkali from wood ashes.

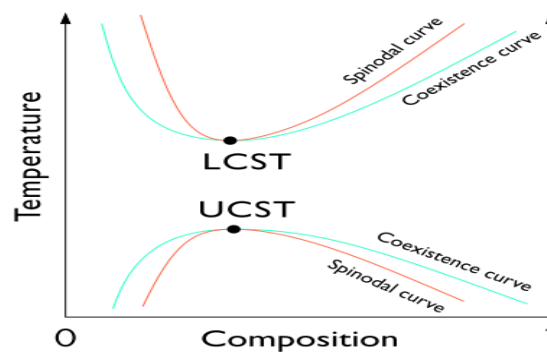
21. Define critical solution temperature. (NOV/DEC 2006)

The temperature at which complete miscibility is reached as the temperature is raised or in some cases lowered used of two liquids that are partially miscible under ordinary conditions.

22. Define LCST and UCST.

LCST –Lower critical solution temperature

UCST – upper critical solution temperature



23. Name four important factors to be considered in the selection of solvents for extraction operation. (NOV/DEC 2005,2004)

The choice of solvent should be done based on the following parameters

- Selectivity: compare the equilibrium ratio of solute in each phase.
- Distribution coefficients: y/x at equilibrium; large values preferable.
- Insolubility: solvent should not be soluble in carrier liquid.
- Recoverability: consider constraints (ie, azeotropes).
- Density: must be different so that phases can be separated by setting.

24. Define the term “Distribution Coefficient?”

Distribution coefficient is defined as the ratio of y^* to x at equilibrium i.e. $= \frac{y^*}{x}$

Where, X = concentration of A in the liquid, mole fraction

Y^* = y is equilibrium with x , mole fraction

Y = concentration of A in the gas, mole fraction

Large values of distribution coefficient are very desirable since less solvent will then be required for the extraction.

25. Give the advantages of leaching by percolation.

Advantages:

- Solids of intermediate size can conveniently be leached by percolation.
- Leaching by percolation is relatively inexpensive.

26. Give the disadvantages of leaching by percolation.

Disadvantages:

- Leaching by percolation will inevitably result in weak solutions of the solute.

27. Define shanks system.

Shanks system is defined as the system which is used to avoid moving the solids physically from tank to tank.

28. What is in situ leaching?

In situ leaching refers to the percolation leaching of minerals in place at the mine, by circulation of the solvent over and through the ore body.

It is used regularly in the removal of salt from deposits below the earth's surface by solution of the salt in water which is pumped down to the deposit.

29. Write the important parameters used for choice of solvent.

- Selectivity
- Distribution coefficients
- Insolubility
- Recoverability
- Density

30. Name the different equipment used for liquid-liquid extraction?

- Mixer-settler extractors
- Centrifugal extractors
- Non agitated extractors

31. Define separation factor. (NOV/DEC 2010)

The effectiveness of solvent B for separating a solution of A and C into its components is measured by comparing the ratio of C to A in the B-rich phase to that in the A-rich phase at equilibrium. The ratio of these ratios is called separation factor.

$$\text{Separation factor} = \frac{(\text{Wt. fraction C in E})/(\text{Wt. fraction A in E})}{(\text{Wt. fraction C in R})/(\text{Wt. fraction A in R})}$$

E-Extract, R-Raffinate, C-Solute

PART B

1. Explain how will you find out the final composition of the solute in the raffinate for immiscible solvent and diluents in single and multistage cross current extraction. (NOV/DEC 2016) [Treybal, Page.No.496-497]
2. A solution of 5% acetaldehyde in toluene is to be extracted with water in a five-stage co-current unit. If 25 kg of water/100 kg feed is used, find the amount of acetaldehyde extracted and the final concentration. (Both by theoretical and graphical method)

The equilibrium relation is given by:

$$(\text{kg acetaldehyde/kg water}) = 2.20 (\text{kg acetaldehyde/kg toluene}). \text{ (NOV/DEC 2016) (class notes)}$$

3. 1000 kgs/hr of a dioxane-water mixture containing 25% dioxane (by weight) is to be continuously extracted in counter fashion with benzene to remove 95% of the dioxane. Assume benzene and water are immiscible with each other. The equilibrium data are as follows:

Wt % dioxane in water phase 5.1 18.9 25.2

Wt % dioxane in benzene phase 5.2 22.5 32.0

(i) Calculate the minimum solvent required in kg/hr and

(ii) If 900 kg/hr of solvent is used, calculate the number of theoretical stages required. (Nov2012, 2013)

Solution:

Basis: 1000 kgs/hr of dioxane –water solution

X – kg of dioxane / kg of water

Y -kg of dioxane / kg of benzene

$$X = \frac{x}{(1-x)}, Y = \frac{y}{(1-y)}$$

x- weight fraction of dioxane in water phase

y – weight fraction of dioxane in benzene phase

Wt % dioxane in water phase(x)	0.051	0.189	0.252
Wt % dioxane in benzene phase(y)	0.052	0.225	0.32
X – kg of dioxane / kg of water	0.05374	0.233	0.337
Y – kg of dioxane / kg of benzene	0.05485	0.2903	0.4706

Amount of feed = 1000 kg/hr

Amount of dioxane in the feed solution = 0.25 * 1000 = 250 kg/hr

Amount of water in the feed solution = 0.75 * 1000 = 750 kg/hr

Dioxane to be removed = 95 % of its amount in feed solution

Dioxane in the final raffinate = 5 % of its amount in feed solution = 0.05*250= 12.5 kg/hr

$$(i) A = F(1 - x_F) = 1000(1 - 0.25) = 750 \text{ kg/hr}$$

$$y_s = 0, y'_s = 0, X_F = \frac{x_F}{1 - x_F} = \frac{0.25}{1 - 0.25} = 0.333 \frac{\text{kg dioxane}}{\text{kg water}}$$

$$X_{NP} = \frac{12.5 \text{ kg dioxane}}{750 \text{ kg water}} = 0.01667$$

From graph $Y'_K = 0.465$, therefore Minimum solvent required

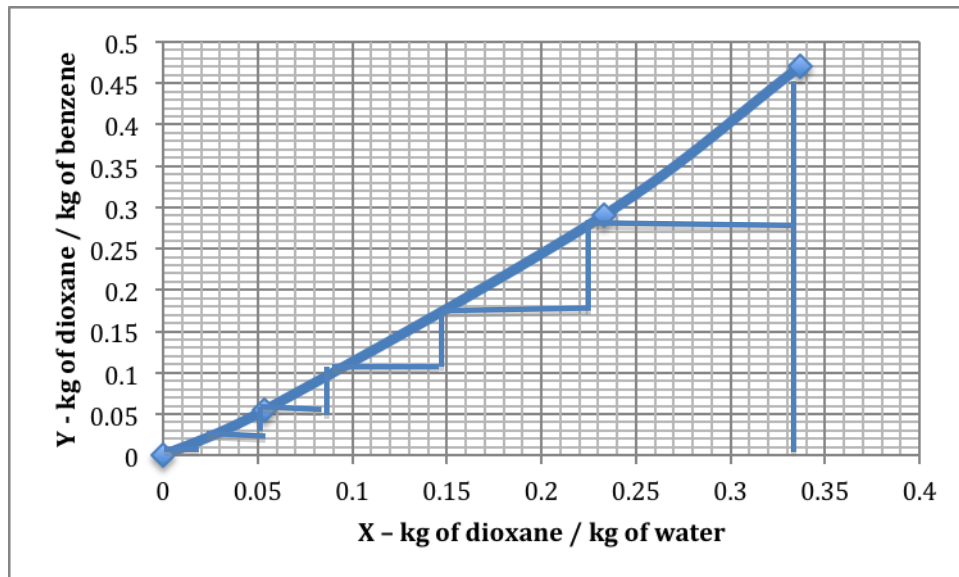
$$\frac{A}{B_m} = \frac{Y'_K - Y'_s}{X_F - X_{NP}} = \frac{0.465 - 0}{0.333 - 0.0167} = 1.47, B_m = 510 \text{ kg/hr}$$

(ii) Solvent B = 900 kg/hr

$$\frac{A}{B} = \frac{750}{900} = 0.8333$$

$$\frac{A}{B} = \frac{Y'_1 - Y'_s}{X_F - X_{NP}} = \frac{Y'_1 - 0}{0.333 - 0.0167} = 0.8333, Y'_1 = 0.2635 \frac{\text{kg dioxane}}{\text{kg benzene}}$$

The operating line is drawn between (X_F, Y'_1) and (X_{NP}, Y'_s)



The number of theoretical stages from the graph is 6

4. Explain Bollman Extractor with a neat sketch. (Nov2012, 13) [Treybal, Page No.742-743]
5. (i) Write briefly about selection of solvent for liquid liquid extraction. (Nov2012, 13) [Treybal, Page No.488-489]
(ii) Write the stepwise procedure for calculating the number of stages when A and B are immiscible for continuous counter extraction operation. (Nov2012, 13) (Nov 2011, 2014) [Treybal, Page No.496-500]
6. A solution containing 20 mass per cent of acetone in water is to be extracted using monochlorobenzene (MCB) containing 0.5% acetone by weight by counter current extraction process. MCB and water may be considered to be immiscible within the operating range. The equilibrium data are as follows:

Kg of acetone Per Kg of water	0.0258	0.0739	0.1605	0.267
Kg of acetone Per Kg of MCB	0.0288	0.0704	0.156	0.237

Compute minimum solvent ratio to obtain a raffinate containing 1% acetone.
(NOV/DEC 2007)[Treybal, Page No.559] (Class notes)

PART C

1. With a neat sketch, explain the working principle of various leaching equipments.
(NOV/DEC 2009)[Treybal, Page No.720-727]
2. Explain the principle, operation and applications of various industrial extraction equipments with neat diagram.(NOV/DEC 2014)) [Treybal, Page No.542-548]
3. Nicotine in water containing 1% Nicotine is to be extracted with kerosene at 200°C water. Water and kerosene are insoluble. Estimate the percentage extraction of Nicotine for the following cases.
 - (i) If 100 kg of feed solution is extracted in a single stage with 150 kg of solvent.
 - (ii) If 100 kg of feed solution is extracted in three theoretical stages using 50kg of fresh solvent in each stage. (NOV/DEC 2011, 2009) [Treybal, Page No.497]

Equilibrium data:

X'	0	0.00101	0.00246	0.00502	0.00751	0.00998	0.0204
Y'	0	0.00081	0.001962	0.00456	0.00686	0.00913	0.0197

Where X' is kg nicotine/kg water and Y' is kg nicotine/kg kerosene.

UNIT V - SOLID FLUID OPERATIONS PART A

1. What is adsorption and give its application? (NOV/DEC 2016)

The adsorption operations exploit the ability of certain solids preferentially to concentrate specific substances from solution onto their surfaces. The components of either gaseous or liquid solutions can be separated from each other.

Adsorption is used to dehumidify air and other gases, to remove objectionable odors and impurities from industrial gases such as carbon dioxide, to recover valuable solvent vapors from dilute mixtures with air and other gases.

2. Define moisture content wet and dry basis. (NOV/DEC 2016)

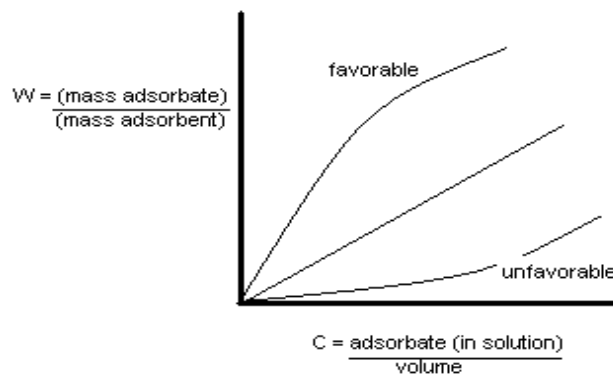
Moisture content (wet basis): The moisture content of a solid or solution is usually described in terms of weight percent moisture, and unless otherwise qualified this is ordinarily understood to be expressed on the wet basis, (i.e) as (kg moisture/kg wet solid)100 = [kg moisture/(kg dry solid+kg moisture)]100 = 100X / (1+X).

Moisture content (dry basis): This is expressed as kg moisture/kg dry solid = X. Percentage moisture, dry basis = 100 X

3. Sketch the shape of different equilibrium adsorption isotherms using an appropriate plot.(APR/MAY 2015)

Adsorption is usually described through adsorption isotherms that is the amount of adsorbate on the adsorbent as a function of its pressure (if gas) or concentration (if liquid) at constant temperature. The adsorption isotherm is the equilibrium relationship between the concentration in the fluid phase and the concentration in the adsorbent particles at a given temperature. The quantity adsorbed is nearly always normalized by the mass of the adsorbent to allow comparison of different materials. "Favorable" isotherms permit higher solid loadings at lower solution concentrations. These tend to start out steep and level out. Isotherms which start out flat are "unfavorable", since they only work well at high concentrations of solute. Usually, as temperature increases the amount adsorbed decreases (permitting thermal regeneration).

Several fits have been proposed for isotherms. A linear isotherm seems to work for very dilute solutions, but not for many others. The *Freundlich isotherm* describes physical adsorption from liquids and can also be used for the adsorption of hydrocarbon gases on activated carbon.



4. Brief the process of drying with the help of drying rate curve. (APR/MAY 2015)

In the first phase (constant rate period) the liquid water moves by capillary forces to the surface in same proportion of moisture evaporation. Moisture movement across the lumber will depend on the wood permeability and the drying rate itself is controlled by external conditions in this period.

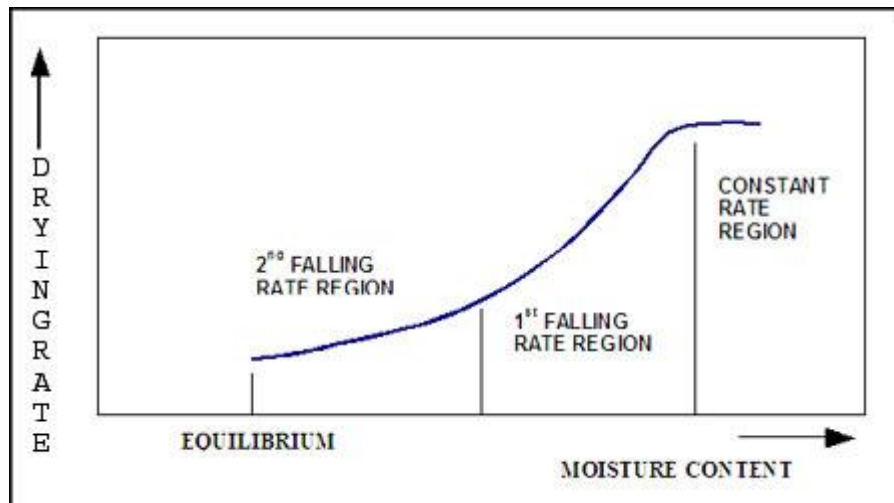


Fig. 1.– Characteristic drying curve for a porous material (Rosen, 1983).

Part of energy received by the surface increase temperature in this region, and the heat transfer to the inner part of lumber starts. When the capillary flow decreases, moisture content at surface reaches the Fiber Saturation Point (FPS) and the first falling rate period begin.

In the last phase (second falling rate period) there is no more liquid water in the lumber, and the drying rate is controlled only by internal resistance (material characteristics) until an equilibrium moisture content is reached

5. Define adsorption hysteresis.(NOV/DEC 2014,2012,2010,2006,2004)

Adsorption hysteresis is said to occur when adsorption and desorption values deviate from one another. The quantity adsorbed is different when gas is being added that it is when being removed. The specific causes of adsorption hysteresis may be linked to differences in the nucleation and evaporation mechanisms inside mesopores.

This may be the result of the shape of the openings to the capillaries and pores of the solid or of complex phenomena of wetting of the solid by the adsorbate.

In any case, when hysteresis is observed, the desorption equilibrium pressure is always lower than that obtained by adsorption.

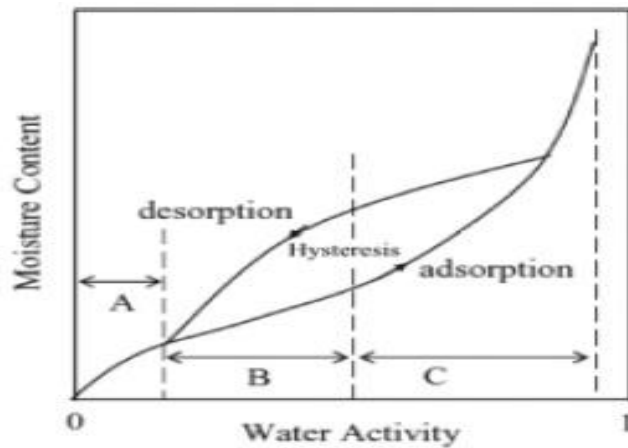
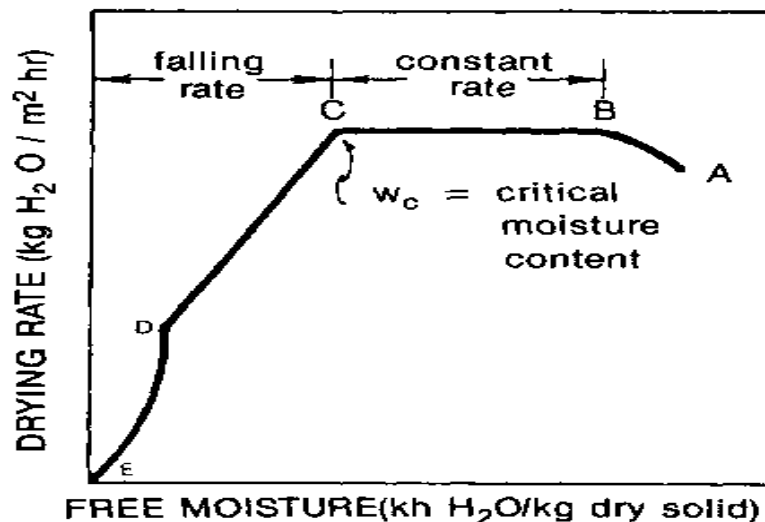


Figure 1. Sorption isotherm for a typical food product, showing the hysteresis.

6. What is critical moisture content? (NOV/DEC 2014)

Critical moisture content, X_C is the moisture content at which the drying rate first begins to drop (under constant drying conditions). It is the average moisture throughout a solid material being dried, its value being related to drying rate, thickness of material, and the factors that influence the movement of moisture within the solid.



7. What is Vander Waals adsorption? (NOV/DEC 2013)

It is a result of intermolecular forces of attraction between molecules of the adsorbent and the adsorbate (substance adsorbed). In this case, the adsorbate merely condenses in a thin on the surface of adsorbent solid. The intermolecular attractive forces that retain the adsorbent on the surface are purely physical and are called Van der waals forces. As these factors are very weak, the adsorbate is loosely bound to the surface of the adsorbent.

8. What type of drier is suitable for drying milk powder? (NOV/DEC 2013)
- Spray driers
 - Vacuum tray dryers

9. What is meant by Free moisture?(MAY/JUNE 2013)

Free moisture:

Moisture contained by a substance in excess of the equilibrium moisture.

10. What is meant by Critical moisture?(MAY/JUNE 2013)

Critical moisture:

Critical moisture content, X_C is the moisture content at which the drying rate first begins to drop (under constant drying conditions). It is the average moisture throughout a solid material being dried, its value being related to drying rate, thickness of material, and the factors that influence the movement of moisture within the solid.

11. Give two examples of adsorption. (MAY/JUNE 2013)

- (i) The removal moisture dissolved in gasoline
- (ii) Decolourization of petroleum products & aqueous sugar solutions.

12. Define: heat of wetting. (NOV/DEC 2012)

When an adsorbent solid is immersed in a pure liquid, the evolution of heat, known as the heat of wetting, is evidence that adsorption of the liquid does occur.

13. Define the term Bound moisture. (NOV/DEC 2011)

Bound moisture is defined as the moisture contained by a substance which exerts an equilibrium vapour pressure less than that of pure liquid at the same temperature.

14. Define the term equilibrium moisture content of solid. (NOV/DEC 2011)

Equilibrium moisture content:

Equilibrium moisture content is defined as the moisture content of a substance when at equilibrium with a given partial pressure of the vapour.

15. Define the term free moisture content of solid. (NOV/DEC 2011)

Free moisture content:

Free moisture content is that moisture contained by a substance in excess of the equilibrium moisture.

16. Define Bound moisture. (NOV/DEC 2010,2008) (MAY/JUNE 2009)

Bound moisture:

Bound moisture is defined as the moisture contained by a substance which exerts an equilibrium vapour pressure less than that of pure liquid at the same temperature.

17. Define unbound moisture. (NOV/DEC 2010,2008) (MAY/JUNE 2009)

Unbound moisture:

Unbound moisture is defined as it is the moisture contained by a substance which exerts an equilibrium vapour pressure equal to that of pure liquid at the same temperature.

18. What is adsorption isotherm? (APR/MAY 2010) (NOV/DEC 2007)

It is obtained by plotting adsorbate concentration in solid phase.

It is a function of adsorbate concentration in a liquid at a phase at a given temperature.

They are of three types

- (i) Linear adsorption isotherm or brunauer emmett isotherm
- (ii) Langmuir isotherm

(iii) Freundlich isotherm

19. What are pendular states of drying? (APR/MAY 2010) (NOV/DEC 2007)

In the first falling rate period after the critical point, the liquid/vapor meniscus retreats into pores of the body. The moisture still exerts its full vapor pressure and is transferred mainly by capillarity, as liquid is in the funicular state.

20. What are funicular states of drying? (APR/MAY 2010) (NOV/DEC 2007)

In the second falling rate period moisture is held in the finest capillaries and evaporation occurs inside the body at the boundary between the funicular (continuous liquid) and pendular (isolated pockets of liquid) regions. Transport in pendular region occurs by evaporation-condensation mechanism. The drying rate decreases sharply and takes place in all inner portions of the material.

21. What are the different types of adsorption isotherms? (APR/MAY 2009)

The different types of adsorption isotherms are

- Freundlich isotherm
- Langmuir isotherm
- Brunauer Emmett Teller isotherm (BET)

22. Define tray efficiency. (APR/MAY 2009)

a Tray efficiency is the fractional approach to an equilibrium stage which is attained by real tray. Three types of tray or plate efficiency are used :

- Overall tray efficiency
- Murphee tray efficiency
- Point efficiency

23. What is heat of wetting? Give example. (MAY/JUNE 2009)

When an adsorbent solid is immersed in a pure liquid, the evolution of heat, known as the heat of wetting, is evidence that adsorption of the liquid does occur. But immersion does not provide an effective method measuring the extent of adsorption.

No appreciable volume change of the liquid which might be used as a measure of adsorption is ordinarily observed, while withdrawal of the solid and weighing it will not distinguish between the adsorbed liquid and that which is mechanically occluded.

24. Write the Freundlich isotherm equation. (NOV/DEC 2008)

The equation is given as $C_a = kS^n$.

n, k are constants determined from experimental data by plotting $\log C_a$ Vs $\log s$.

The slope of the plot gives the dimensionless quantity n which indicates the favourability of adsorption process.

The adsorption is favourable for $n < 1$ and unfavourable if $n > 1$.

The dimension of k depends on the value of n.

25. Discuss the factors, which affect the rate of drying. (MAY/JUNE 2007)

The sample should not be too small.

The sample should be similarly supported in a tray or frame.

It should have the same ratio of drying to nondrying surface.

It should be subjected to similar conditions of radiant heat transfer.

The air should have the same temperature, humidity and velocity (both speed and direction with respect to the sample).

26. Define differential heat of adsorption. (MAY/JUNE 2007)

It is denoted by H and is defined as the heat liberated at constant temperature when unit quantity of vapour is adsorbed upon a large quantity of solid already containing adsorbate.

A large quantity of solid is used, such that the adsorbate concentration is unchanged.

$$d \ln \bar{p}^* / d \ln p = (-H)M/(\lambda_r M_r)$$

Where

p^* = Adsorption pressure

p = vapour pressure

M = mol wt. of vapour

M_r = mol.wt. of reference substance

λ_r = latent heat of vaporization of reference substance at the same temperature

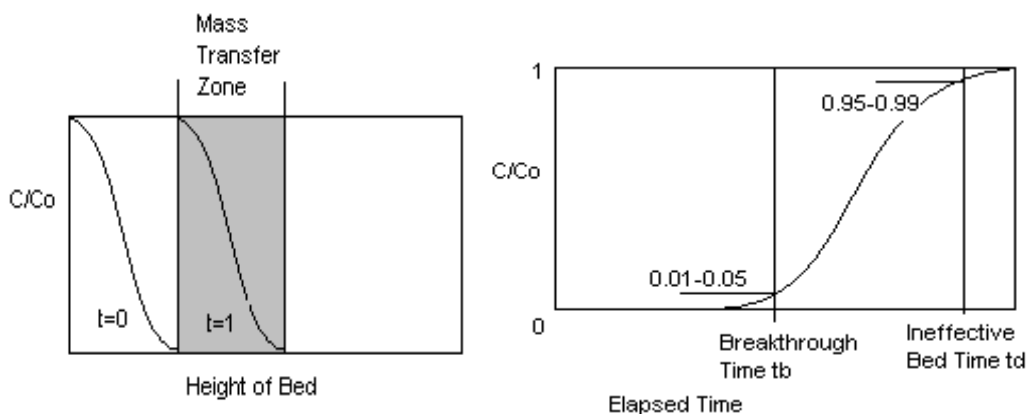
27. Recommend the correct choice of driers used for drying granular materials. (NOV/DEC 2006)

- (i) Turbo-type driers
- (ii) Through-circulation driers
- (iii) Rotary driers
- (iv) Tray driers

28. Explain about break-through curve. (NOV/DEC 2005)

The fluid emerging from the bed will have little or no solute remaining -- at least until the bulk of the bed becomes saturated. The *break point* occurs when the concentration of the fluid leaving the bed spikes as unadsorbed solute begins to emerge. The bed has become ineffective. Usually, a *breakpoint composition* is set to be the maximum amount of solute that can be acceptably lost, typically something between 1 and 5 percent.

As the concentration wave moves through the bed, most of the mass transfer is occurring in a fairly small region. This *mass transfer zone* moves down the bed until it "breaks through". The shape of the mass transfer zone depends on the adsorption isotherm (equilibrium expression), flow rate, and the diffusion characteristics. Usually, the shape must be determined experimentally.



29. Differentiate between physical adsorption and chemisorption. (NOV/DEC 2005)

Physisorption	Chemisorption
Forces of attraction are van der Waals' forces	Forces of attraction are chemical bond forces
Low enthalpy of adsorption (20 - 40 kJ/mole)	High enthalpy of adsorption (200 - 400 kJ/mole)
This process is observed under conditions of low temperature	This process takes place at high temperatures
It is not specific	It is highly specific
Multi-molecular layers may be formed	Generally, monomolecular layer is formed
This process is reversible	This process is irreversible

30. State the Freundlich equation and define the terms used in the equation. (NOV/DEC 2004)

- ❖ The equation is given as $C_a = kS^n$.
- ❖ n,k are constants determined from experimental data by plotting $\log C_a$ Vs $\log s$.
- ❖ The slope of the plot gives the dimensionless quantity n which indicates the favourability of adsorption process.
- ❖ The adsorption is favourable for $n < 1$ and unfavourable if $n > 1$.
- ❖ The dimension of k depends on the value of n.

31. Name the types of adsorption

- (i) Physical adsorption (or) Vander waals adsorption – reversible phenomenon, is the result of intermolecular forces of attraction between molecules of the solid & the substance adsorbed.
- (ii) Chemical adsorption (or) chemisorptions (or) activated adsorption – is the result of chemical interaction between the solid & the adsorbed substance.

32. Recommend the correct choice of driers used for drying fruit juices.(NOV/DEC 2006)

- (i) Spray driers
- (ii) Fluidized bed dryers

PART B

1. Explain with neat diagram the construction details and working principles of Tray driers & Spray driers. (Nov 2016, 2012, 2013) [Treybal, Page No.662-664 ,695]
2. Explain fixed bed adsorbers. (NOV/DEC 2016,2015,2010) [Treybal, Page.No.623-625]

3. Explain the factors affecting the rate of adsorption and break through curve in adsorption. (Nov 2012,2010,) [Treybal, Page No.632-636]
4. A slab with a wet weight of 5 kg originally 50 % moisture (wet basis). The slab is 600 by 900 by 75 mm thick. The equilibrium moisture content is 5 % of the total weight when in contact with air of 20 °C and 20 % humidity. The drying rate is given below for contact with air of the above quality at a definite velocity. Drying is from one face only. How long will it take to dry the slab to 15 % moisture content (wet basis). (Nov 2012, May 2010)
- | | | | | | | | |
|----------------------------------|-----|-----|-----|-----|-----|-----|-----|
| Wet slab weight, Kg | 9.1 | 7.2 | 5.3 | 4.2 | 3.3 | 2.9 | 2.7 |
| Drying rate Kg/m ² hr | 4.9 | 4.9 | 4.4 | 3.9 | 3.4 | 2.0 | 1.0 |

Solution:

Basis: 5 kg of the total wet solid

Let x be the kg of moisture in the wet solid

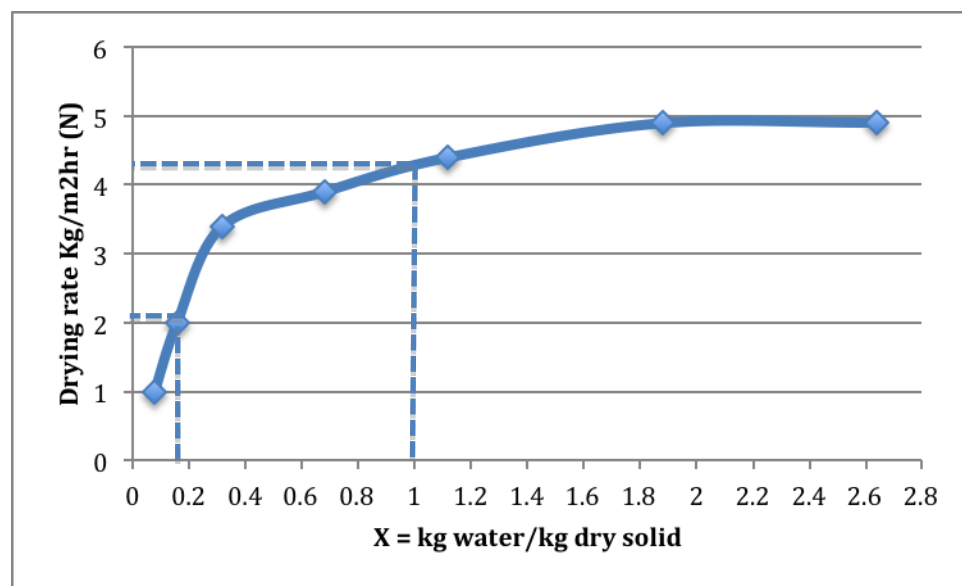
Weight of the dry solid = (5 - x) kg

Amount of moisture content = 50 %

$$\therefore x = 50\% (5) = 2.5 \text{ kg}$$

$$\text{Drying area} = (600 \times 10^{-3}) \times (900 \times 10^{-3}) = 0.54 \text{ m}^2$$

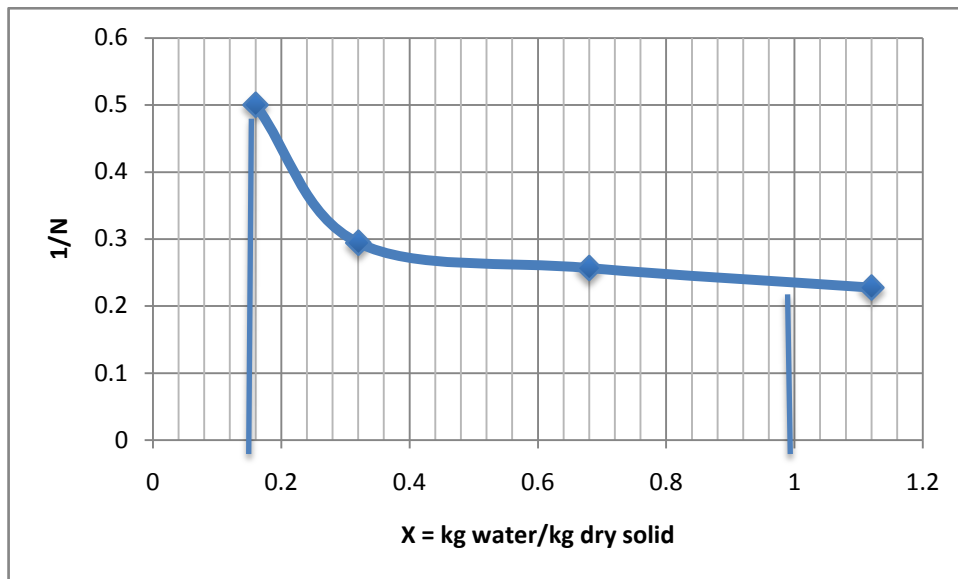
N vs X is plotted.



$$X_1 = \frac{50}{100 - 50} = 1.0, X_2 = \frac{15}{100 - 15} = 0.176$$

Drying is in the falling rate period only, Further, the falling rate is not linear. Hence the drying time is to be evaluated by graphical integration.

1/N vs X is plotted, The area under the curve is plotted between $X_1 = 1.0$ and $X_2 = 0.176$



Area under the curve = No. of squares * scale on x axis * scale on y axis = $13 \times 0.2 \times 0.1 = 0.26$

$$\theta_f = \frac{L_S}{A} \int_{0.176}^1 \frac{dx}{N} = \frac{2.5}{0.54} * 0.26 = 1.203 \text{ hrs}$$

The time required to reduce the moisture content to 15 % = 1.2 hrs

5. An aqueous solution is colored by small amounts of impurity which is to be removed by adsorption on activated carbon. The color intensity which is proportional to the concentration of the colored substance was measured on an arbitrary scale. It is desired to reduce the color to 10 % of its original value, 9.6. Estimate the amount of adsorbent used for single stage. (Nov 2013)

Kg of carbon/ kg of solution	0	0.001	0.004	0.008	0.02	0.04
Equilibrium Color	9.6	8.6	8.3	4.3	1.7	0.7

Solution:

Basis: 1 kg of the solution

Let X be adsorbate concentration (Color units/ kg carbon) and Y* be the equilibrium color (Color units / kg solution)

Initial color $Y_0 = 9.6$ (Color units / kg solution)

Therefore $Y_1 = 10\%$ of 9.6 = 0.96 (Color units / kg solution)

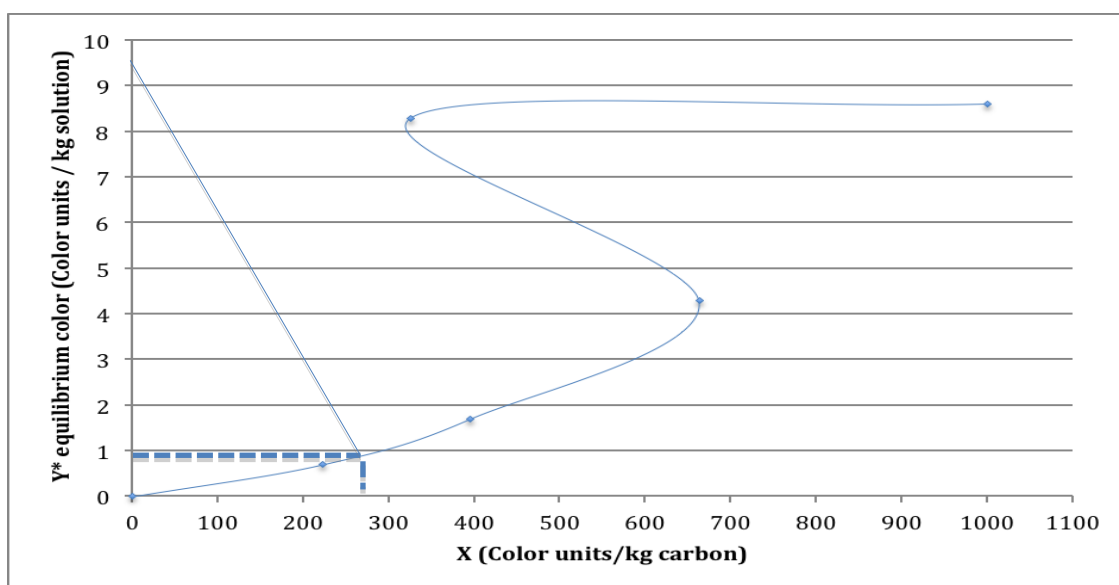
$L_s = 1$ kg of the solution

Assuming fresh adsorbent is used $X_0 = 0$

The value of X_1 corresponding to the value of Y_1 is 280

$$\frac{S_s}{L_s} = \frac{Y_0 - Y_1}{X_1 - X_0} = \frac{9.6 - 0.96}{280} = 0.0308 \text{ kg carbon / kg solution}$$

Kg of carbon/ kg of solution	Y* equilibrium color (Color units / kg solution)	X adsorbate concentration (Color units/ kg carbon)
0	9.6	-
0.001	8.6	1000
0.004	8.3	325
0.008	4.3	662.5
0.02	1.7	395
0.04	0.7	222.5



The amount of adsorbent used for single stage = 0.0308 kg carbon / kg solution

6. (a) Distinguish between the two types of adsorption phenomena bringing out their essential features.(MAY/JUNE 2013) [Treybal, Page.No. 566-567]
 b) Explain briefly the following: Adsorption isotherm and adsorption hysteresis. (APR/MAY 2015)[Treybal, Page.No. 569-573]

PART – C

1. Obtain an expression for the drying time in the case of a substance having both falling rate and constant rate drying periods. (NOV/DEC 2014,2013)[Treybal, Page.No. 667-676]
2. Explain the principle and applications of rotary drier and represent their different modes of operation with neat diagram. (NOV/DEC 2014,2008,2007) [Treybal, Page.No. 689-692]
3. (i) explain the phenomena of adsorption of concentrated solutions.(MAY/JUNE 2013)][Treybal, Page.No.582-584]
 (iii) Discuss briefly the operation of Higgin's contactor. (MAY/JUNE 2013)][Treybal, Page.No. 613-614]

Reg. No. :

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Question Paper Code : 50196

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2017

Fifth Semester

Biotechnology

BT6503 – MASS TRANSFER OPERATION

(Regulations 2013)

Time : Three Hours

Maximum : 100 Marks

Answer ALL questions

PART – A

(10×2=20 Marks)

1. Define molecular diffusion.
2. State Fick's first law of diffusion.
3. Write the material balance equation in counter current absorption.
4. What is the effect of pressure and temperature on absorption ?
5. Define the term "Relative Volatility".
6. Write the total material and component balance for two component system of the entire distillation column.
7. What is "Distribution Coefficient" ?
8. What are the factors depends on leaching action ?
9. Distinguish between physical adsorption and chemical adsorption.
10. Write the material balance for the single stage adsorption operation.

PART – B

(5×13=65 Marks)

- a) Discuss in detail about various theories of mass transfer. (13)

(OR)

- b) Derive the Reynolds analogy starting from fundamental transport equation for momentum, heat and mass. State the assumption made and limitations of the equation. (13)

12. a) A soluble gas is absorbed in water using a packed tower. The equilibrium relationship is $Y_e = 0.06 X_e$ and terminal conditions are :

	Top	Bottom
x	0	0.08
y	0.001	0.009

If the individual height of transfer units based on liquid phase and gas phase respectively are $H_x = 0.24$ m and $H_y = 0.36$ m, determine the height of packing.

(OR)

- b) Explain in detail about the various types of industrial absorbers with neat sketch.
13. a) Derive Rayleigh equation in a Differential Distillation.

(OR)

- b) Write briefly about the procedure to determine the number of theoretical plates required in the distillation column using the Ponchan-Savarit method.
14. a) i) Discuss briefly about the qualities to be considered for the selection of the solvent in extraction.
- ii) Nicotine (c) in a water (A) solution containing 1% nicotine is to be extracted with kerosene (B) at 20°C . Water and kerosene are essentially insoluble:
- a) determine the percentage extraction of nicotine if 100 kg of feed solution is extracted once with 150 kg solvent.
- b) Repeat their theoretical extractions using 50 kg solvent each.

Equilibrium data :

$X' = \text{kg nicotine/kg of water}$	0	0.0010	0.0025	0.0050	0.0075	0.0100	0.0204
$Y' = \text{kg nicotine/kg of kerosene}$	0	0.0008	0.0020	0.0046	0.0069	0.0091	0.0187

(OR)

- b) Explain in detail about the total material balance for the Single Stage and Multistage Counter Current Extraction with neat sketch.

15. a) Give a brief note on various types of batch and fixed bed adsorption equipments available for adsorption of a solute from gaseous and liquid stream with neat sketch. (13)

(OR)

- b) i) Explain in detail about drying rate curve. (6)
 ii) Illustrate the material and energy balance expressions for continuous direct heat dryer. (7)

PART - C

(1×15=15 Marks)

16. a) A continuous fractionating column is to be designed to separate 30,000 kg/hr of a solution of benzene and toluene, containing 0.4 mass fraction of benzene into an overhead product containing 0.97 mass fraction of benzene and a bottom product containing 0.98 mass fraction of toluene. A reflux ratio of 3.5 kg of reflux per kg of product is to be used. The feed will be liquid at its boiling point and the reflux will be returned to the column : (15)
- i) Determine the top and bottom product
- ii) Determine the number of theoretical stages needed using McCabe Thiele method :

x	0.773	0.659	0.555	0.459	0.370	0.288	0.211	0.141	0.075	0.013
y	0.897	0.831	0.757	0.678	0.591	0.496	0.393	0.281	0.161	0.031

(OR)

- b) Give a detailed note on various types of batch and continuous dryers with neat sketch. (15)

Reg. No.

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Question Paper Code : 80171

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2016.

Fifth Semester

Bio Technology

BT 6503 — MASS TRANSFER OPERATION

(Regulations 2013)

Time : Three hours

Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What is meant by molecular diffusion?
2. State Fick's first law of diffusion.
3. Define Gas absorption?
4. Give two-example for gas absorption?
5. What is "Relative volatility"? Give the expression for the relative volatility for a binary mixture.
6. Define total reflux.
7. Write the properties of a good solvent for extraction.
8. What is the principle of leaching?
9. What is adsorption and give its application?
10. Define moisture content wet and dry basis.

PART B — (5 × 16 = 80 marks)

11. (a) Derive from the first principle the general rate equation for the steady state unidirectional molecular diffusion in gases at rest and in laminar flow for the following cases.
 - (i) For diffusion of A through non-diffusing B.
 - (ii) Forequimolal counter diffusion.

Or

- (b) Oxygen (A) is diffusing through nondiffusing carbon monoxide (B) under steady-state conditions. Total pressure is $1 \times 10^5 \text{ N/m}^2$ and temperature is 0°C . The partial pressure of oxygen (A) at two planes 2 mm apart are 13000, 6500 N/m^2 respectively. The diffusivity of the mixture is $1.87 \times 10^{-5} \text{ m}^2/\text{s}$. Calculate the rate of diffusion of oxygen in kmol per second through each sq.m of the two planes.
12. (a) An air-ammonia mixture containing 5% ammonia by volume is absorbed in H_2O in a packed column operated at 20°C and 1 atm pressure so as to recover 98% of NH_3 . If the inert gas flow rate in the column is 1200 kg/hr m^2 , calculate.
- The minimum mass velocity of water for this column
 - The number of transfer unit in the column taking the operating liquid rate to be 1.25 times the minimum
 - The height of the packed lower taking the overall transfer coefficient, K_{Ga} to be $128.0 \text{ kg mole hr(m}^3)(\text{atm})$. The relationship for equilibrium in the column is $y = 1.154 x_1$ where y and x are in mole fraction units.

Or

- (b) Derive an equation for finding out the height of a packed column operating in a counter current method.
13. (a) What is flash distillation and explain.

Or

- (b) Explain the process of Azeotropic distillation.
14. (a) Explain how will you find out the final composition of the solute in the raffinate for immiscible solvent and diluents in single and multi stage cross current extraction.

Or

- (b) A solution of 5% acetaldehyde in toluene is to be extracted with water in a five-stage co-current unit. If 25 kg of water/100 kg feed is used, find the amount of acetaldehyde extracted and the final concentration. (Both by theoretical and graphical method)

The equilibrium relation is given by:

$$(\text{kg acetaldehyde/kg water}) = 2.20 (\text{kg acetaldehyde/kg toluene}).$$

15. (a) Explain fixed bed adsorbers.

Or

- (b) Explain tray drier with a neat diagram.

Reg. No. :

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Question Paper Code : 27088

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2015.

Fifth Semester

Biotechnology

BT 6503 — MASS TRANSFER OPERATION

(Regulations 2013)

Time : Three hours

Maximum : 100 marks

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. State Fick's first law of diffusion.
2. What are the factors that affect the mass transfer rate between two fluids?
3. Define absorption factor.
4. What are gas industrial absorbers? Give example for the same.
5. Explain Raoult's Law.
6. What are azeotropes? Sketch a $T - x - y$ diagram for a minimum boiling point azeotrope?
7. What is the principle of Leaching?
8. What are the factors to be considered when optimizing the design and operation of the extraction processes?
9. Write any four commonly used adsorbents.
10. Define moisture content on wet and dry basis.

PART B — ($5 \times 16 = 80$ marks)

11. (a) Derive from the first principle the general rate equation for the steady state unidirectional molecular diffusion in gases at rest and in laminar flow for the following cases
 - (i) For diffusion of A through non-diffusing B.
 - (ii) For equimolar counter diffusion.

Or

- (b) In a mass transfer apparatus operating at atmosphere the individual mass transfer coefficients have the following values

$$K_x = 22 \text{ kg mol/m}^2\text{h}(\nabla x = 1)$$

$$K_y = 1.07 \text{ kg mol/m}^2\text{h}(\nabla y = 1)$$

The equilibrium composition of the gaseous and liquid phases are characterized by Henry's Law $P^* = 0.08 \times 10^6 \text{ mm Hg}$

- (i) Determine the overall mass transfer coefficient K_x and K_y
 - (ii) How many times the diffusion resistance of the liquid phase differs from that of the gaseous phase?
12. (a) Explain channeling, loading, flooding.

Or

- (b) 5000 kg/hr of a SO_2 - air mixture containing 5% by volume SO_2 is to be scrubbed with 200,000 kg/hr of water in a packed tower. The exit concentration of SO_2 is reduced to 0.15%. The tower operates at 1 atmosphere. The equilibrium relationship is given by $y = 30x$

$$\text{where } y = \frac{\text{moles } \text{SO}_2}{\text{mole air}}; x = \frac{\text{Mole } \text{SO}_2}{\text{Mole } \text{H}_2\text{O}}$$

If the packed height of the tower is 420 cm, Estimate the height of transfer unit (HTU).

13. (a) What is flash distillation and explain with diagram?

Or

- (b) Explain with a neat diagram the fractionating process.
14. (a) Explain how the number of stages can be determined for immiscible solvents in a multistage cross current extraction.

Or

- (b) Acetone is to be recovered from an aqueous solution containing 20% acetone by weight using kerosene as a solvent. The distribution of acetone in water and kerosene follows the relationship. $X = 6.45 Y$

where $X = \text{Kg of acetone per kg of water}$, $Y = \text{Kg of acetone per kg of kerosene}$.

If this extraction is done in three equilibrium simple contacts using 5 kg of solvent per kg of initial solution in each stage, Find the concentration of acetone in the final raffinate. Both by theoretical and graphical method.

15. (a) Name the commercial adsorbents available and their applications.

Or

(b) Explain tray drier with a neat diagram.

Question Paper Code : 31165

B.E./B.Tech. DEGREE EXAMINATION; NOVEMBER/DECEMBER 2013.

Fifth Semester

Biotechnology

BT 2304/BT 54/10155 BT 505 — MASS TRANSFER OPERATIONS

(Regulation 2008/2010)

Time : Three hours

Maximum : 100 marks

Graph Sheets should be provided.

(Any missing data may be assumed suitably)

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. Define molecular diffusion.
2. What is the effect of temperature and pressure on diffusivity?
3. Define : Absorption Factor.
4. State four characteristics of solvents used in absorption operation.
5. Define relative volatility and depict its significance in distillation.
6. What is HETP?
7. When do you prefer liquid-liquid extraction?
8. State four metals separated from its ore by leaching operations.
9. What is Vander Waals adsorption?
10. What type of drier is suitable for drying milk powder?

PART B — (5 × 16 = 80 marks)

11. (a) Ammonia is diffusing through a stagnant mixture consisting of one third Nitrogen and two-thirds Hydrogen by volume.

The total pressure is 1 atm and the temperature is 200°C. Calculate the rate of diffusion of ammonia through a film of gas 0.5 mm thick, when ammonia concentration changes across the film is 12% and 7% by volume. The diffusivities at 200°C and 1 atm pressure are

$$D_{AB} = 5.391 \times 10^{-5} \text{ m}^2 / \text{s} \text{ and } D_{AC} = 1.737 \times 10^{-4} \text{ m}^2 / \text{s}.$$

Or

- (b) (i) Explain Higbie's penetration theory. (8)
(ii) Explain Reynold's analogy. (8)
12. (a) Obtain an expression for the determination of the height of the absorption tower. (16)

Or

- (b) A gas from a petroleum distillation column has its concentration of H_2S reduced from 0.03 Kg mole H_2S / Kg mole inert gas to 1% of its value by scrubbing with a triethanolamine with water as a solvent in a countercurrent tower of height 7.79m operating at 300°C and 1 atm. The equilibrium relation is $Y=2X$. Pure solvent enters the tower and leaves containing 0.013 Kg mole H_2S / Kg mole of solvent. If the flow of inert hydrocarbon gas is 0.015 kg mole/ m^2s and gas phase controls the mass transfer, calculate the overall coefficient for absorption. (16)
13. (a) (i) Explain the principle of steam distillation and its applications. (10)
(ii) Explain the assumptions involved in McCabe – Thiele method. (6)

Or

- (b) A feed mixture of A and B (45 mole % A and 55 mole % B) is to be separated into a top product containing 96 mole% A and bottom product having 95 mole% B. The feed is 50% vapour and reflux ratio is 1.5 times the minimum. Determine the number of ideal trays required and the location of feed tray. Given $\alpha_{AB} = 2.8$. (16)

14. (a) 1000 kg of 20% Dioxane solution in water is to be extracted using pure benzene as solvent to recover 95% of Dioxane at 25°C. Water and Benzene are immiscible. Determine

- (i) solvent for single batch operation
- (ii) the solvent required for 4 cross current stages in which equal amount of solvent is used per stage. Equilibrium data: (16)

Wt % of Dioxane				
in water	5.1	18.9	25.2	
Wt % of Dioxane				
in Benzene	5.2	22.5	32	

Or

- (b) (i) Explain the construction and operation of Bollman extractor with a neat sketch. (10)
- (ii) Explain the different process parameters to increase the leaching of oil from vegetable seeds. (6)

15. (a) A solid adsorbent is used to remove impurity from an aqueous solution. The original colour value is 48. It is to be reduced to 10% of its original value using the following data. Find the quantity of fresh adsorbent for 1000 kg of solution

- (i) For a single stage operation and
- (ii) A two stage cross current operation with an intermediate colour value of 24. (16)

<u>kg of adsorbent</u>	0	1.0	4.0	8.0	20	40
kg of solution						
Equilibrium colour	48	43	31.5	21.5	8.5	3.5

Or

- (b) (i) Explain the construction and operation of a spray drier with a neat sketch. (10)
- (ii) Explain the characteristics of drying rate curve. (6)