GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3150501
Semester –V
Subject Name: Mass Transfer Operations -I

Type of course: Professional Core course

Prerequisite: Basics of fluid dynamics, heat transfer and thermodynamics

Rationale: The objective of this course is to study the principles of mass transfer and their applications to separation and purification processes in chemical industry. This course is intended to explain detailed fundamentals of mass transfer operations such as diffusion, mass transfer coefficient, inter phase mass transfer etc.. and its application for in depth study and for solving problems pertaining to some mass transfer operations such as in detail. This course also enables the students to understand principal and working of various mass transfer equipments like gas absorption columns, crystallizers, and extractors etc..

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
4	0	2	5	70	30	30	20	150

Content:

Sr. No.	Content	Total Hrs
1	**Introduction:** Definition and aim of mass transfer operations, Classification of mass transfer operation with examples, Direct Vs Indirect Mass transfer operations, choice of separation method, Methods of conducting mass transfer operations, Design principles	4
2	**Molecular Diffusion in Fluids:** Definition of molecular and eddy diffusion, Ficks law, Concept of N & J Flux, Steady state molecular diffusion in fluids at rest and in laminar flow, concept of effective diffusivity. Diffusivity of gases, Diffusivity of liquids.	10
3	**Mass Transfer Coefficients:** Mass transfer in laminar and turbulent regions, F and k type mass transfer coefficients, Film, Penetration and surface renewal theories, Analogies between momentum, heat and mass transfer, Dimensionless numbers	6
4	**Inter Phase Mass Transfer:** Concept of equilibrium, diffusion between phases, Two resistance theory, Local overall mass transfer coefficient, controlling mass transfer resistances.	4
5	**Gas Absorption:** Equilibrium Solubility of gases in liquids, Ideal and non-ideal solutions, Choice of solvent for absorption, Material balance and liquid to gas ratio for absorption, Counter current multi stage operation (isothermal), Absorption factor, Continuous contact	8

	equipments, Overall coefficient and Transfer units, Concept of HETP and HTU, NTU and jH factor, Industrial absorbers. Dilute solutions, Absorption with chemical reaction	
6	**Equipments for Gas Liquid Operations:** *Gas Dispersed*: Sparged vessels, Mechanically agitated vessels, Gas-Liquid contact, Tray Tower, Tray tower internals, Different types of trays, Weirs, Downcomers and criteria of their selection, Flooding, Loading, Coning, Weeping & dumping in tray tower *Liquid Dispersed*: Ventury scrubber, Wetted wall towers, spray towers, Packed Towers, Packed tower internals, Different types of packings and their selection criteria, mass transfer coefficient for packed towers, Co-current flow of gas & liquid, End effects and axial mixing, Tray tower vs. Packed tower.	8
7	**Liquid-Liquid Extraction:** Ternary liquid- liquid equilibrium and tie line data, system of three liquids-one pair partially soluble, two partially soluble, two partially soluble liquids and one solid, multi-component system, stage wise contact, Single stage & multistage extraction, Co-current and cross current extraction, Continuous counter current multistage extraction with and without reflux, Theory & performance of continuous contact equipments, Single stage & multistage equipments, Applications of liquid-liquid extraction.	10
8	**Leaching:** Steady state and unsteady state leaching operations, Single stage leaching, Multistage cross current and counter current leaching, Rate of leaching, Recovery of solvent vapors, Application of leaching, Leaching equipments	6
9	**Crystallization:** Saturation, Nucleation, Principle of crystallization, Crystallization rate, Equilibria and yields, Nucleation, Crystal growth, Caking of crystals, Application of crystallization, Crystallization equipments	4

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
10	30	20	10	-	-

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Reference Books:

1. R. E. Treybal, Mass transfer operations, 3rd edition, Mc-Graw Hill international, New Delhi, 1983.
2. J. F. Richardson, J H Harkar, Coulson and Richardson's Chemical Engineering, Volume-2, 5th edition, Butterworth Heinemann, 2002.
3. Binay K. Dutta, Principles of mass transfer and separation processes, 2nd edition, Prentice Hall of India, 2007.
4. W. L. McCabe, J.C .Smith & Harriott, Unit Operations of Chemical Engineering, 6th edition Mc-Graw Hill international, 2001.
5. C. J. Geankoplis, Transport processes and unit operations, 3rd edition, Prentice Hall of India, 1993.

Course Outcomes:

Students should be able to

Sr. No.	CO statement	Marks % weightage
CO-1	Describe fundamentals of diffusion; inter phase mass transfer and mass transfer coefficients.	40
CO-2	Explain various mass transfer operations and their equipments used in chemical industries.	20
CO-3	Apply theoretical and analytical aspects of mass transfer operations to deal with complex problems of separations.	20
CO-4	Solve problems pertaining to various mass transfer operations like gas absorption, liquid-liquid extraction, crystallization and leaching	20

List of Experiments:

1. To determine the diffusion co-efficient of CCl_4 in air & it's variation with temperature.
2. Determine mass transfer co-efficient of liquid (water) evaporation to atmospheric air at elevated temperature.
3. To find out the liquid side mass transfer coefficient K_{La} for the absorption of CO_2 in NaOH in the packed column.
4. To prepare ternary diagram for a system of three liquid –one pair partially soluble.
5. To determine the % extraction for the benzoic acid from dilute aqueous solution using toluene as solvent.
6. To study multistage (cross current) liquid-liquid extraction for extracting acetic acid from benzene using water as solvent.
7. To determine the stage efficiency and the overall recovery of NaOH for multistage cross current leaching operation for leaching of NaOH from mixture of NaOH and $CaCO_3$ using water as a solvent.
8. To find out crystal yield with & without seeding

Major Equipments:

Gas Absorption column, batch crystallizer, Diffusion assembly, Packed column etc.

List of Open Source Software/learning website:

1. Students can refer to video lectures available on the websites including NPTEL.
2. Students can perform experiments on Virtual Lab