GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3150405
Semester –V
Subject Name: Chemical Engineering Fundamentals-II

Type of course: Professional Core course

Prerequisite: Chemical Engineering Fundamentals-I

Rationale:
The objective of this course is to study fundamentals of mass transfer and reaction engineering by under graduate students of biotechnology. The objective of mass transfer is to study the principles of mass transfer and their applications to separation and purification processes in process industries. The objective of reaction engineering is to study various reactions and determine its kinetics. This course enables students to study various ideal reactors and determine reactor volume required for desired processes.

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	Module Weight %
	Part I Mass Transfer		
1.	**Introduction:** Classification of mass transfer operation, Direct Vs Indirect Mass transfer operations, choice of separation method, Methods of conducting mass transfer operations, Design principles	4	7
2.	**Molecular Diffusion in Fluids:** 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, Estimation of Diffusivity of gases and liquids.	9	15
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	10
4.	**Inter Phase Mass Transfer:** Concept of equilibrium, diffusion between phases, Two resistance theory, Local overall mass transfer coefficient, controlling mass transfer resistances.	4	7
5.	**Diffusion in Solids:** Fick's law in diffusion through solids, Types of solid diffusion	2	2
6.	**Gas Absorption:** Equilibrium Solubility of gases in liquids, Ideal and non-ideal solutions, Choice	6	10

	of solvent for absorption, Material balance and liquid to gas ratio for absorption, Counter current multi stage operation (isothermal), Absorption factor, Packed towers		
7.	**Liquid-Liquid Extraction:** Applications of liquid-liquid extraction, Ternary liquid- liquid equilibrium and tie line data, system of three liquids-one pair partially soluble, two pair partially soluble, stage wise contact, Single stage & multistage extraction, extraction equipments	5	8
8.	**Leaching:** Steady state leaching operations, equilibrium diagrams, Single and Multistage leaching, Applications of leaching, Leaching equipments-shanks system for leaching	4	7
	Part II Reaction Engineering		
1.	**Kinetics of Homogenous Reactions** Classification of reactions, reactions rate, elementary and non-elementary reactions. Kinetic models for non-elementary reactions, Testing kinetic models, Temperature dependant term of rate equations from Arrhenius theory, collision and transition state theory, Activation Energy and Temperature Dependency	7	12
2.	**Interpretation of Batch Reactor data** Constant volume batch reactor, analysis of total pressure data, determine kinetics for 1st order and 2nd order for various cases, differential methods of analysis of data for constant volume systems, variable volume reactors	7	12
3.	**Introduction to Reactor Design for single reactions** Ideal reactors, space-time and space velocity, performance equation for batch reactor, CSTR and PFR, Introduction to semi batch reactor, size comparison of reactors, recycle reactors, introduction to parallel reactions.	6	10

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
15	30	20	5	-	-

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. Octave Levenspiel, Chemical reaction engineering, 3rd edition, John Willey & Sons (Asia) Pvt. Ltd., 2015
6. J.M.Smith, Chemical engineering kinetics, 2nd edition, McGraw Hill
7. H. Scott Fogler, Elements of chemical reaction engineering, 3rd edition, Prentice Hall of India Pvt. Ltd.

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 and various equipments for different operations.	45
CO-2	Solve problems pertaining to various mass transfer operations like gas absorption, liquid-liquid extraction and leaching.	22
CO-3	Explain reaction rate, theories of temperature dependency and mechanism of reactions.	13
CO4	Determine kinetics of various reactions and reactor volume required for ideal batch reactor, CSTR and/ PFR for specific reactions.	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 prepare ternary diagram for a system of three liquid –one pair partially soluble.
4. To determine the % extraction for the benzoic acid from dilute aqueous solution using toluene as solvent.
5. To study multistage (cross current) liquid-liquid extraction for extracting acetic acid from benzene using water as solvent.
6. 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.
7. To determine the activation energy of the reaction between sodium thiosulphate and HCl using Arhenious Equation for unknown kinetics.
8. To determine the kinetics of the reaction between ethyl acetate and sodium hydroxide at room temperature by the integral method of analysis.
9. To determine the activation energy and frequency factor for reaction between ethyl acetate and sodium hydroxide.
10. To determine the kinetics of the reaction between ethyl acetate and sodium hydroxide at room temperature by the differential method of analysis.

11. To determine effect of initial concentration on rate of reaction between sodium thiosulfate and hydrochloric acid.

Major Equipments:

Gas Absorption column, Diffusion assembly, CSTR, PFR 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