GUJARAT TECHNOLOGICAL UNIVERSITY

CHEMICAL ENGINEERING (30)
MEMBRANE SEPARATION PROCESSES
SUBJECT CODE: 2713011
SEMESTER: I

Type of course: Chemical Engineering (ELECTIVE I)

Prerequisite: Basics of mass transfer operations

Rationale: Membranes are applied in a range of processes from selective separation to solvent and material recovery. This course will enable students to understand membrane-based separation problems by acquiring in-depth knowledge in the area of membrane separation mechanisms, transport models, membrane materials and modules etc. The focus will be particularly on various applications of membrane science and technology.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks						Total Marks
L	T	P	C	Theory Marks		Practical Marks				
				ESE (E)	PA (M)	PA (V)		PA (I)		
						ESE	OEP	PA	RP	
3	2	2	5	70	30	20	10	20	0	150

Content:

Sr. No.	Topics	Teaching Hrs.	Module Weightage
1	**Rate governed and equilibrium membrane separation processes**:- Fundamentals, Types of membranes, Modules, Flow patterns, Preparation and characterization of membranes, Melt pressing, Film stretching, Sol-gel peptization, Interfacial polymerization etc. Measurement of pore size and solute rejection properties	7	13
2	**Reverse Osmosis**:- Design and operating parameters, Various transport models, Kedem-katchalsky model, Spiegler-kedem model, Solution-diffusion model, Concentration polarization and flux decline, Design of an RO module, Forward Osmosis	5	30
3	**Nanofiltration:-** Transport mechanism in NF membranes, Parameters affecting the performance of NF membranes, Fouling model, determination of various resistances.	5	
4	**Ultrafiltration**:- Factors affecting performance of ultrafiltration, Resistance model, Gel polarization model, Fouling and flux decline, Micellar-enhanced ultrafiltration, Affinity ultrafiltration, microfiltration advances	7	
5	**Membrane gas Separation:-** Membranes for gas separation, Fundamental mechanism of gas transport, Knudsen diffusion, Molecular sieving, Solution diffusion, Dual sorption model, Factors affecting gas permeation, Complete mixing model, Solution of equations, Equations for multicomponent mixtures, Cross- flow model, Countercurrent Model, Applications	7	13
6	**Pervaporation:-** Mass transfer and thermodynamics aspects of pervaporation, Temperature drop at membrane interface	5	18
7	**Dialysis:-** Principle of dialysis, Dialysis systems, Mass transfer in	4	

	dialysis, Modeling of solute transport in hemodialyzer, Advantages of diffusion dialysis, Application of diffusion dialysis, Electrodialysis		
8	**Liquid Membrane:-** Benefits of liquid membrane, Bulk liquid membrane, Emulsion liquid membrane, Thin sheet supported liquid membrane, Hollow fibre supported liquid membrane, Applications	5	18
9	**Facilitated Transport:-** Mechanism of facilitated transport, Coupled Transport, Carrier agents, Competitive facilitated transport with two permeants, active and passive transport, Some potential applications of facilitated transport.	5	
10	**Membrane Reactor:-** Membrane bioreactor, Membrane distillation	4	8

Reference Books:

1. Membrane Handbook Eds. By W. S. W. Ho and K. K.Sirkar
2. Membrane technology and applications, Baker, R.W., 2nd ed., John Wiley 2004
3. Synthetic membranes: Science, Engineering and Applications, Eds. By P. B. Bunge, H. K. Lonsdale and M. N. Depinho.
4. Ultrafiltration and Microfiltration Handbook, (2^{nd} Edition), Munir Cheryan, CRC Press.
5. Basic Principles of Membrane Separation, Mudler J, (2^{nd} Edition), Springer

Course Outcome:

After learning the course the students should be able to:

1. Apply various transport models for the calculation of membrane fluxes and the extent of separation for various membrane systems.
2. Identify the types of experimental data needed for the calculation of membrane parameters
3. Select a membrane process and design components to carry out a specific separation
4. Apply advanced membrane techniques to solve environmental as well as chemical industries problems.
5. To Review the importance and relevance of separation process with the help of membrane in industry.

List of Experiments :

1. Experimental determination of permeate flux, permeate rejection and permeate characteristics in RO, NF, UF and MF membranes.
2. The above experiment should be repeated with different membranes and fluxes may be compared
3. Determination of Membrane Permeability using different membranes.
4. Swelling characteristics of membrane used in separation of aqueous-organic mixture
5. Preparation and characterization of membrane.
6. Flux and selectivity in Pervaporation.
7. Experiment on emulsion liquid membrane using oil-water emulsion or in separation of phenol/ heavy metals etc.
8. Application of solution diffusion model with some experiments.
9. A case study with selected waste water.
10. Determination of various mass transfer resistances during pressure driven membrane process.
    Term paper submission on any specific membrane application in industrial operation

Open ended projects:

The practical work at masters must be largely consisting of open ended projects. In each case a sample set may be provided and the faculty member may be empowered to select appropriate problems for practical

work. At the end of semester before submission of marks of PA and term work, the faculty member will upload the three best problems done by the students during the practical hours.

Types of OEP for membrane separation process can be as under

- Design of non working/working module of any membrane separation viz Reverse osmosis, dialysis, membrane reactor.

- Application of any membrane separation process for effluent/wastewater treatment of nearby chemical industries.

- Recovery of heavy metals from effluent of electroplating industries, using emulsion liquid membrane**.**

Major Equipments:

Working / Non working modules of reverse osmosis unit, ultafiltration unit, micro and nano filtration unit, membrane reactor, membrane bioreactors, etc.

List of Open Source Software/learning website

1. Literature available for membrane sciences & its applications in industry.
2. NPTEL
3. MIT open course lecture on equipment design.