Spring 2019

CHE 603-102: Separation Process Principles

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ChE 603-101 Separation Process Principles (Spring 2019) (Tiernan 107)
Instructor: K.K. Sirkar (371 Tiernan, x 8447)
Prerequisites: Undergraduate ChE course in Separations

Course Content: Description of separation, separation indices, closed and open systems, binary, multicomponent and continuous mixtures, recycle, reflux, time-dependent processes. Physicochemical basis for separation in equilibrium, field and membrane separation processes, flux-force relations, chemical potential profiles, band broadening, phase equilibria. Closed systems: Separation factors in equilibrium, field and membrane processes, focusing techniques. Effect of chemical reaction on separation in equilibrium and membrane processes. Open stage analysis, role of bulk flow vis-a-vis force direction, bulk flow parallel to force, bulk flow(s) perpendicular to force, time-dependent systems. Distillation, absorption, extraction, crystallization, zone refining, capillary electrophoresis, ion exchange, chromatography, PSA, electrophoresis, dielectrophoresis, electrostatic precipitation, centrifugal separations, HGMS, reverse osmosis, ultrafiltration, dialysis, electrodialysis, liquid membranes, gas permeation, pervaporation, parametric pumping, etc. Stage and point efficiencies. Reaction-separation systems.

Textbook

1. "Separation of Molecules, Macromolecules and Particles: Principles, Phenomena and Processes". Kamalesh K. Sirkar, Cambridge University Press, New York, 2014. (Kept in the Library).

Recommended References (LIBRARY, RESERVED SECTION)

1. Li, N. (ed.), Recent Advances in Separation Techniques, AIChE Symposium Series 120, vol. 68, 1972 (Article by P. R. Rony, pages 89-104). (Kept in the Reserve Section).

2. Karger, B. L., L. R. Snyder and C. Horvath, An Introduction to Separation Science, 1973, Wiley Interscience. (Recommended).

3. King, C. J., Separation Processes, McGraw-Hill, 1980. (Recommended).

4a. Seader, J. D. and E. J. Henley, Separation Process Principles, Wiley, 1998, 2nd Edn. Wiley, 2006, 3rd Edn., Wiley 2011.

4b. Wankat, P.C., Separation Process Engineering, 2nd Ed., Prentice Hall, 2007.

5. Giddings, J. C., Separation Science and Technology, 13, 3, 1978. (Reserved in Library).

6. Lee, H. L., E. N. Lightfoot, J. F. G. Reis, and M. D. Waissbluth, Pages 1-70 in Recent

Developments in Separation Science, Vol. III, part A, N. N. Li (ed.), Chemical Rubber Co., Cleveland, OH, 1997.

7a. Giddings, J. C. Unified Separation Science, John Wiley Interscience, 1991.

7b. Elving, P.J., E. Grushka and I. M. Kolthoff, Treatise on Analytical Chemistry: Theory and Practice Part 1, Vol. V, Wiley, 1982. Read Article by J. C. Giddings. (Kept in the Reserve Section).

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9. Sherwood, T. K., R. L. Pigford and C. R. Wilke, Mass Transfer, McGraw-Hill, 1975.

10. Smith, B. D., Design of Equilibrium Stage Processes, McGraw-Hill, 1963.

11. Helfferich, F., Ion Exchange, McGraw-Hill, 1962.

12. Bird, R. B., W. E. Stewart and E. N. Lightfoot, Transport Phenomena, Wiley, 2nd. Edn. 2002.

13. Smith, J. M. and H. C. Van Ness, Introduction to Chemical Engineering Thermodynamics, 3rd Edition, McGraw-Hill, 1975 (also future editions)--.

14. Ho, W.S.W. and K.K. Sirkar, Membrane Handbook, Van Nostrand Reinhold, 1992; Kluwer Academic, Boston (2001).

15. Holland, C. D., Fundamentals and Modeling of Separation Processes, Prentice-Hall, 1975.

16. Progress in Separation and Purification, Vols. 1, 2, 3 and 4, E. S. Perry et al. (eds.), 1968 onwards, Interscience.

17. Svarovsky, L., Solid-Liquid Separation, Butterworths, London, 1977.

18. Lewis and Randall, Thermodynamics, 2nd Edition, McGraw-Hill, 1961.

19. Merten, U., Desalination by Reverse Osmosis, MIT Press, 1966.

20. Schweitzer, P. A., (Ed.) Handbook of Separation Techniques for Chemical Engineers, Interscience (1979, 1997).

21. Schoen, H. M., New Chemical Engineering Separation Techniques, Interscience, 1962.

22. Belter, P. A., E. L. Cussler and W. S. Hu, Bioseparations, New York, Wiley, 1988 (Recommended textbook).

23. Wankat, P. C., Rate-Controlled Separations, Elsevier, 1990.

24. Garcia, A. A., M. R. Bonen, J. Ramirez-Vick, M. Sadaka and A. Vuppu, Bioseparation Process Science, Blackwell Science, 1999.

25. Pratt, H.R. C., Countercurrent Separation Processes, Elsevier, 1967.

26. Ladisch, M.R., Bioseparations Engineering: Principles, Practice, and Economics, Wiley-Interscience, New York, 2001.

Lecture Outline

Week/s	Topic
1.5	Description of Separation; Closed, Open Systems; Binary, Multicomponent, Continuous Mixtures; Recycle, Reflux, Time-dependent Processes.
1.5	Physicochemical Basis for Separation in Equilibrium, Field and Membrane Separation Processes; Fluxes-Forces; Chemical Potential Profiles; Band Broadening; Phase Equilibria; Interphase Transport.
1.5	Ideal Separation Factor in Equilibrium, Field and Membrane Processes; Isoelectric Focusing; Isopycnic Sedimentation.
1.5	Role of Chemical Reactions in Separations; Gas Absorption; Distillation; Solvent Extraction; Crystallization; Enzymatic Resolution; Chromatographic Separations. **FIRST EXAM** (Feb 28 or Mar 7).
2.0	Open Stage Analysis; Bulk Flow Parallel to Force; Elutriation, Capillary Electrophoresis; Centrifugal Elutriation; Depth Filtration; Flash Distillation; Solvent Extraction; Zone Melting; Drying; Filtration; RO, Continuous Stirred Tank Separator; Crystallization, UF.
2.5	Bulk Flow of One Phase Perpendicular to Force; Fixed Bed Processes (Adsorption; Ion Exchange; Chromatography); Crossflow Membrane Processes; Electrophoretic Processes; Centrifugal Separations. **SECOND EXAM**. (April 4 or April 11).
2.3	Bulk Flow of Two Phases Perpendicular to Force; Absorption, Distillation, Extraction; Moving Bed Processes; Simulated Moving Bed Processes; Membrane Processes: Dialysis, Electrodialysis, Gas Separation.
1.2	Bioseparations; Water Treatment; Chemical Separations; Hydrometallurgical Separations. **FINAL EXAM**.

GRADING INFORMATION

There will be three open-book written examinations: one on February 28 or March 7 (Thursday), one on April 4 or 11 (Thursday) and then the final exam. The first two exams will last between 1.5-2 hours. The final exam will be for 2.5-3 hours. The grading of the examinations will be weighted based on the time allotted and the nature of the questions. In general, the distribution will be: 40% final exam; 30% for the other two exams.

OFFICE HOURS

I am available for discussions on Tuesdays, 4:30-5:30 pm and Wednesdays, 4:45-5:45 pm.