NEW JERSEY INSTITUTE OF TECHNOLOGY
OTTO H. YORK DEPARTMENT OF CHEMICAL, BIOLOGICAL AND PHARMACEUTICAL ENGINEERING

Pharmaceutical Separation Processes---PhEn 614 (Fall, 2016)

Instructor: Professor Kamalesh K. Sirkar (371 Tiernan Hall, x 8447)

Course Outline: This course will begin with a description of separation processes in general and pharmaceutical separations in particular. Then it will focus on how to describe separation in a variety of systems under a variety of conditions. Physicochemical basis of separations, flux-force relations and phase equilibrium phenomena will be considered next to provide a fundamental background to equilibrium separation processes, external field-based processes and membrane-based separations in closed systems. The role of chemical reactions in such processes will be considered subsequently with a view to enhancing separations. Different separation processes will be studied then in open systems; the open systems with flow in and out will be categorized with respect to the direction of forces vis-a-vis the direction/s of motion/s of bulk phase/s. Specific processes to be studied in detail are: absorption, distillation, extraction, crystallization, adsorption, ion exchange, chromatography, moving bed processes, freeze drying, microfiltration/ultrafiltration, reverse osmosis, pervaporation, electrophoresis, dielectrophoresis, centrifugation etc. A pharmaceutical product manufacturing flow sheet will be studied at the end.

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 Textbooks and 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 Textbook).

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

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).

8. Treybal, R.E., Liquid Extraction, McGraw-Hill, 1962 (2nd Edition).

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; Introduction to Pharmaceutical Separation Needs.
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/Pharmaceutical Separations; Solvent Extraction; Absorption; Crystallization; Enzymatic Resolution; Chromatographic Separations. **FIRST EXAM**
2.0	Open Stage Analysis; Bulk Flow Parallel to Force; Capillary Electrophoresis; Deadend Filtration; Flash Distillation; Solvent Extraction; Drying; Continuous Stirred Tank Separator; Crystallization, Precipitation.
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**.
2.0	Bulk Flow of Two Phases Perpendicular to Force; Absorption, Distillation, Extraction; Moving Bed Processes; Simulated Moving Bed Processes; Membrane Processes.
1.5	Crystallization; Freeze Drying; Supercritical Extraction; Antibiotic Manufacturing Processes. **FINAL EXAM**.

New Jersey Institute of Technology
Otto H. York Department of Chemical, Pharmaceutical and Biological Engineering
PhEn 614: Pharmaceutical Separation Processes (Fall, 2016) (FMH 306)
Instructor: Prof. K.K. Sirkar (Office: 371 Tiernan Hall, Ext. 8447)

GRADING INFORMATION

There will be three open-book written examinations: one on October 20 (Thursday), one on November 22 (Tuesday) 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 Thursdays, 4:0-5:00 PM.