Bioseparations

(BPE 502 / 3 credits).

## Instructor: Dr. Bandaru Ramarao

Lectures, conferences, discussions and laboratory in Bioprocess Engineering. Topics covered include: description of particulates of biological origins, colloids, charge and colloidal stability, separation techniques of interest in processing materials of biological origin: sedimentation, flotation, filtration, centrifugation, membrane processes – ultra, nano and RO processes, dialysis, adsorption, chromatography, solvent extraction, crystallization and drying.

## OBJECTIVES:

A successful student should be able to:

* Demonstrate competency in working with different units for measurement of force, work, power and other quantities of interest in separations.
* Identify separation techniques for bioprocesses. Demonstrate an understanding of principles of colloidal science including diffusion, osmotic pressure, charge on biointerfaces, attractive and repulsive potentials between particles in suspensions, DLVO theory of colloidal stability, stability of particles with macromolecules.
* Describe flocculation of cells, effects of pH and solution chemistry (ionic conditions).
* Describe filtration of suspensions. Identify and select filter media and equipment. Differentiate between crossflow and deadend filtration. Scaleup and design filtration systems.
* Identify sedimentation principles. Calculate sedimentation velocities, apply Stokes’ law and other forms of settling calculations. Compare and perform engineering analysis on production centrifuges.
* Analyze extraction, phase separation and describe partitioning equilibria. Perform countercurrent stage calculations. Scaleup and design of extractors.
* Identify and analyze adsorption phenomena, describe dynamics of adsorption columns. Describe plate models for chromatography and column dynamics. Describe different chromatographic techniques.
* Identify protein solubility, precipitation kinetics, design of precipitation systems.
* Crystallization phenomena, scaleup and design crystallizers.
* Perform drying calculations, calculate relative amounts of bound and unbound water in wet solids before drying, scaleup dryers.

## MAJOR CONCEPTS OR METHODOLOGIES:

* Principles of colloidal science including diffusion, osmotic pressure, charge on biointerfaces, attractive and repulsive potentials between particles in suspensions, DLVO theory of colloidal stability, stability of particles with macromolecules.
* Filtration of suspensions, crossflow and deadend filtration. Scaleup and design filtration systems.
* Sedimentation principles. Engineering analysis on production centrifuges.
* Extraction, phase separation and countercurrent stage calculations. Scaleup and design of extractors.
* Adsorption phenomena, dynamics of adsorption columns. Gradient chromatography, affinity chromatography.
* Protein solubility, precipitation kinetics, design of precipitation systems.
* Crystallization phenomena.
* Drying calculations, scaleup dryers.
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## Chapter 1. Basic Concepts in Bioseparations.

Classification. Small Biomolecules.

Particulate Products. Measures of Quality.

Yield & Purity of Products.

EXERCISE 1

## Chapter 2. Colloidal and Interfacial Phenomena in Bioseparations. 1,2

Definitions. Sols, suspensions and foams. Particle size distributions.

Stokes' law. Brownian motion of small particles. Random walk. Diffusivity. Stokes-Einstein theory.

Osmotic Pressure. Thermodynamics. Donnan Equilibrium.

Surface tension and surface energy. Thermodynamics of surfaces.

Origins of particle charge. Electrical double layer. Gouy-Chapman theory. Zeta Potentials. Poisson-Boltzman equation. Debye-Huckel approximation.

Dispersion Forces between surfaces. London - van der Waals' forces of interactions.

Interaction potential between surfaces.

DLVO Theory. Schulze-Hardy rule.

Critical coagulation concentration. Effect of electrolyte.

EXERCISE 2

## Chapter 3. Cell Lysis and Flocculation.

Cell Lysis. Osmotic and chemical cell lysis. Mechanical methods. Flocculation. Elementary considerations. Perikinetic and orthokinetic flocculation. Stability of dispersions.

EXERCISE 3.

## Chapter 4. Filtration.

Flow through porous media – Darcy’s law and permeability. Kozeny Carman equation.

Dead-end or cake filtration. Constant pressure & constant rate filtrations. Definition of specific filtration resistance. Crossflow filtration. Membranes.

EXERCISE 4.

## Chapter 5. Sedimentation and Centrifugation.

Principles of sedimentation. Stokes law. Sedimentation coefficient. Kynch’s theory. Compressible sedimentation. Polydispersity.

Centrifugation & Engineering analysis. Design and scale up.

EXERCISE 5.

## Chapter 6. Adsorption.

Equilibrium relations. Gibbs adsorption. Langmuir & Freundlich isotherms. Activity coefficients in adsorption. Adsorption from solution. Liquid and gas phase adsorption. Multicomponent adsorption.

EXERCISE 6.

## Chapter 7. Extraction.

Partition coefficients, phase separation. Stage calculations. Scale-up and design of extractors.

EXERCISE 7.

## Chapter 8. Chromatography.

Column chromatography. Dynamics. Plate models. Dispersion effects. Adsorbents. Scale up.

EXERCISE 8.

## Chapter 9. Precipitation & Crystallization.

Protein solubility. Precipitate formation phenomena. CSTR. Methods of precipitation.

Nucleation & crystal growth. Batch crystallizers. Protein crystallization. Scale-up and design.

EXERCISE 9.

## Chapter 10. Drying.

Drying principles. Water isotherms. Heat and mass transfer. Scale-up and design.

EXERCISE 10.

## Chapter 11. GUEST LECTURES.

COURSE BOOKS & REFERENCES

## COURSE TEXT

Bioseparations Science and Engineering.

Roger G. Harrison, P. Todd, S. R. Rudge and D. P. Petrides.

Oxford University Press, 2003. ISBN – 0-19-512340-9.

## COURSE REFERENCES

Bioseparations Engineering. Principles, Practice and Economics.

Michael R. Ladisch. Wiley-Interscience, 2001.

Heimenz, P. C. `Principles of Colloid and Surface Chemistry.' Marcel-Dekker Inc. 2nd Edition (1987).