CHE 449 – Bioseparations

Spring 2016

Classes: Mon, Wed & Fri, 3:35 PM – 4:25 PM, Business 108

Course Website: www.angel.psu.edu

Instructor: Manish Kumar, manish.kumar@psu.edu, 155 Fenske Lab, 865-7519
Office hours: Walk in anytime available (door open and not in a meeting)
Mon, Wed, Thurs, (most Fri) 4:30- 5:30 PM also by appt.

TA: Tingwei Ren, txr942@psu.edu
Office hours: Thursdays either 6-8 or 6:30 – 8:30 in 133A or 101 Fenske
(see document on Angel for specific location/timing for each week)

Required Text: **None required, Hand written lecture notes (incomplete) will be posted (organized according to course outline), other materials will also be posted**

Recommended Text: *Bioseparations Science and Engineering*
Todd, Harrison, Rudge, and Petrides

Other texts

1. Belter, PA; Cussler, EL; and Hu, W-S, Bioseparations: Downstream Processing for Biotechnology, John Wiley and Sons, 1988
2. Juan A. Asenjo, Separation Processes in Biotechnology, Marcel Dekker, Inc., 1990
3. Garcia AA, Bioseparation Process Science, Blackwell Science

Software: SuperPro Designer (by Intelligen Inc) is a widely used design and costing software used by biotech and pharmaceutical industries. This software is installed on all computers in the ChemE computer lab. This software will be briefly introduced in the later part of the course.

Open Fridays: On many Fridays (not all) we will focus on interactive work. We will focus on important equations and what they mean (including derivations if required), guest lectures, problem solving, tours, experimental work, or a discussion. As class progresses, you can also suggest activities or specific agenda items.

Course Objectives:

The overall objective of this course is to provide students a solid background in the principles, applications and practice of important technologies used for the separation and

purification of biological products, ranging from small primary metabolites and biopharmaceuticals to recombinant proteins. By the end of the course students will be able to:

1. Appreciate the complexity of biological samples and the ever-growing need for efficient separation processes to economically recover bioproducts
2. Understand the physical parameters governing mass transfer and extend this understanding to the separation of biological mixtures
3. Identify the relevant properties of a biological mixture leading to the appropriate choice of unit operations for effecting separation / Understand the relevant design parameters of each unit operation
4. Perform design and scale-up calculations for specific separations including centrifugation, filtration, chromatography, extraction, precipitation and membrane processes
5. Understand the experimental data required to design and scale-up a separation process. Provide a general experimental strategy for obtaining such data
6. Develop outlines of overall separation schemes that could be used to achieve the required removal of key impurities and contaminants

Focus Areas: I would like to emphasize two particular areas that I think are critical to career development for students in chemical engineering. This is based on the assumption that most of the class will be entering the workforce either as engineers or as graduate students, where such skills are important.

7. ***Group Work***. Almost all professional work is done in teams. Thus an important objective of the class is for you to learn how to work in teams. All homework assignments will be group work. You will be allowed to form your own group on the first Friday of class. Groups of 3 are recommended for collaboration on HWs.
8. **Practical Experience**. In class we will focus a little more than usual Chemical Engineering classes on the practical side of technologies. The goal is to make it a practice-oriented class with emphasis on industrial scale equipment, field trips, and possibly pilot plant experiments. The primary mode of instruction will be using case studies which also lends it self to discussion of specific industry-specific practices and design.

Approximate Course Grading Outline

Homework Assignments: approx biweekly ~ 20%

Problem sets are primarily to be used as study tools, reflecting the types of questions that will show up on the exams, but may be more time consuming. Attempting to solve the problem sets in a timely manner will help you to identify topics you are not clear on. They will be due on

Fridays. You can work together with your groups and your group name should be on the answer sheet but **everybody needs to hand in individual HWs**.

Exams:	Exam 1— on or around February 24th	~ 25%
	Exam 2— on or around March 30th	~ 25%
	Exam 3 – Exam week	~ 30%

These dates and times need to be confirmed and room locations determined. Firm times and locations will be announced in class and via Angel mail. Review sessions will be scheduled the before each exam.

Comments:

Late assignments will not be accepted since homework solutions will be made available after class period in which assignments are due.

Students should feel free to ask for help while working on the problem sets. Solutions to problem sets should be turned in individually but the work could be a group effort with your team. Students within a team may work together to solve the problems but may not copy work from other teams. Solutions which are copied from another group / student will be considered as plagiarism and will be handled accordingly.

Please do not hesitate to ask for additional clarification on these policies at any time during the semester.

Course Outline and Approximate Lecture Schedule

Most Materials on Angel will follow the numbering scheme described below. I will post all class notes within this numbering scheme.

1.0 Intro Lecture (Lecture 1)
01/11/16
2.0 Bioproducts Intro (Lecture 2) 01/13/16
3.0 Case Study 1: Penicillin
3.1 Penicillin Intro (Lecture 3)
01/15/16
HW1 Due **01/15/16**
3.2 Filtration
3.2.1 Filtration Intro (Lecture 3) 01/15/16
3.2.2 Filtration Equations (Lecture 4/5) 01/20/16

3.2.2 Filtration Equations (Lecture 6) –compressible cakes and washing 01/20/16
3.2.3 Filtration Equipment (Lecture 7) 01/23/16
3.2.4 Rotary Vacuum Filtration (Lecture 7/8) 01/25/16

HW2 Due **01/29/16**

3.3 Extraction
3.3.1 Extraction Intro (Lecture 8) 01/27/16
3.3.2 Extraction Equations (Lecture 8)
3.3.3 Multistage Extraction (Lecture 9) 01/29/16
3.3.4 Mixer Settler Design/Intro Centrifugal Extraction (Lecture 10) 02/01/16
3.3.5 Extraction Equipment / Example (Lecture 11) 02/03/16
3.3.6 Pod Extractor and Scale-up (Lecture 12) 02/05/16

3.4 Crystallization
3.4.1 Crystallization Intro (Lecture 13) 02/08/16
3.4.2 Continuous Crystallizer Mass Balance (Lecture 14) 02/10/16
3.4.3 Crystallization Example/ Equipment (Lecture 15) 02/12/16

3.5 Drying
3.5.1 Drying Intro (Lecture 15) 02/12/16
3.5.2 Drying Equations and Equipment (Lecture 15) 02/12/16

HW 3 Due **02/12/16**

Review Session 02/22/16

Exam 1 02/24/16

4.0 Case Study 2: Herceptin

4.1 Herceptin Intro (Lecture 16) 02/15/16
4.2 Centrifugation (Lecture 17/18) 02/17, 02/19
4.2.1 Fundamentals 02/15/16
4.2.2 Equipment 02/15 and 02/17
4.2.3 Scale-up 02/17/16
4.2.4 Sigma Analysis (Bowl Centrifuge) 02/17/16
4.2.5 Disk Bowl Centrifuge 02/19/16

Lab Demonstration (Bowl Centrifuge) **03/04/16**

4.3 Adsorption (Lecture 19/20/21) 02/22 -03/04
4.3.1 Intro
4.3.2 Adsorption Column Equations/Example
4.3.3 Yield
4.3.4 Washing /Eluting Adsorption column

HW 4 Due **03/04/16**

4.4 Membranes (Diafiltration/Ultrafiltration)
4.4.1 Intro (Lecture 22) 03/14
4.4.2 Diafiltration Mass Balance (Lecture 23/Lecture 24) 03/14-03/16
4.4.3 UF Mass Balance (Lecture 25) 03/16-03/18
4.4.4 Concentration Polarization (Lecture 26) 03/21
4.4.5 Concentration Polarization (Lecture 27) 04/01
4.4.6 Virus Filtration Lecture (Lecture 28, **04/04**) 04/04

Guest Lecture **03/23**

Guest Lecture **03/25**

HW 5 Due	**03/25/16**
Review Session	03/28
Exam 2	**03/30**
Merck Plant Visit	**04/15**
6.0 Case Study 3: Insulin	
6.1 Insulin Intro (Lecture 30)	04/06
6.2 Cell Lysis (Lecture 30/Lecture 31) 04/09	
Lysis Field Trip	04/20
6.3 Insulin recovery- Chem conversion(Lecture 32)	04/11
6.4 Insulin Purification (Lecture 33)	04/13
6.5 Chromatography (Lecture 34, 35)	04/13, 04/20
HW 6 Due	**04/15/16**
5.0 Plant Layout Heuristics (Lecture 36-38) 04/20-04/25	
HW 7 Due	**04/29/16**
7.0 Process Economics (Superpro Designer) 04/25-04/29	
Final Exam	**(TBD)**