CHEMICAL AND BIOMOLECULAR ENGINEERING 140: CHEMICAL PROCESS ANALYSIS
Fall 2016
SYLLABUS

Professors David B. Graves and Jeffrey A. Reimer
(http://india.cchem.berkeley.edu/~reimer)
101D/101C Gilman Hall
graves@berkeley.edu/reimer@berkeley.edu

Graduate Student Instructors: Elizabeth Corson, Jackie Maslyn, Karl Schaettle

Office hours

Professor Reimer M, Th 4-5 pm 101C Gilman
Professor Graves T, F 2-3 pm 101D Gilman

GSI office hours:
Monday, 10:00 - 11:00 AM 433 Latimer Hall
Monday, 2:00 - 3:00 PM Bixby North
Monday, 4:00 - 5:00 PM Chemistry Library-100E
Tuesday, 5:00 - 7:00 PM Chemistry Library-100E
Friday, 2:00 - 3:00 PM Chemistry Library-100F

Description

The analysis and design of chemical and physical rate processes using conservation of material and energy within multiple-equipment systems. Concepts of control volume, basis, mass conservation, element balances, and energy conservation in open and closed systems are applied in both steady-state and transient situations.

Prerequisite knowledge and/or skills

- Introductory chemistry including understanding of chemical reactions, reaction rate expressions, stoichiometry, and ideal liquids and gases.
- Mathematical ability to solve simple ordinary differential equations and simultaneous linear and non-linear algebraic equations. Knowledge of elementary algebra and functions.
- Freshman-level physics understanding of mechanics and energy.
- Computer skills for creating graphics, doing calculations, and accessing information.

Course Prerequisite(s)

- General Chemistry and Quantitative Analysis (Chem 4B)
- Physics for Scientists and Engineers (Physics 7B)
- Introduction to Computer Programming for Scientists and Engineers (Eng 7 or equivalent)

Course Objectives and Outcomes

Objectives – the students learn:

- how to analyze experimental data and subsequent equation representations by dimensional consistency;
- how to set control volumes and perform steady-state and transient mass balances for complex chemical processes both with and without multiple chemical reactions;
- the contrasting behavior of continuous stirred tank, batch, and plug-flow reactors;
- the criteria for chemical reaction and phase equilibria and how to apply those criteria to equilibrium conversion and phase-separation behavior;
- the concept of multiphase mass transfer, mass transfer rates;
- the equilibrium stage and its role in separation processes;
- the concepts of energy, work, heat, and heat transfer in open and closed systems in the context of the first law of thermodynamics;
- how to set control volumes and perform steady-state and transient energy balances for simple processes with and without chemical reactions.

Outcomes – Students must be able to:

- analyze mass conservation in complex chemical processes, including recycle and purge;
- solve isothermal mass balances to design batch stirred tank reactor (BSTR), continuous stirred tank reactors (CSTR), and plug-flow reactors (PRF);
- use tabulated and/or graphical representation of thermodynamic data to analyze and design processes;
- analyze simple multistage separation processes in co-current and countercurrent operation;
- distinguish between open, steady-state and closed transient forms of energy conservation;
- analyze energy conservation in complex chemical processes including recycle and purge;
- formulate transient energy balances in BSTR with external heating or cooling;
- solve simultaneous energy and mass balances in chemical processes.

Topics Covered

1. model building, conservation of mass, and hydraulic residence times
2. steady-state hydraulic systems, conservation of mass in steady-state systems, process flow-sheeting and problem definition, recycle
3. modeling chemically reacting systems
4. complex kinetics, batch reactors, CSTRs, multiple steady states
5. elements of process economics
6. multiphase mass transfer, mass-transfer rates, timescales
7. equilibrium stages, multiphase unit operations, countercurrent design, McCabe-Thiele

analysis

8. dimensional analysis and Buckingham Pi Theorem, tray hydraulics
9. conservation of energy (1st Law for Open Systems)
10. mixing, phenomenological heat transfer (Newton's law of cooling), heat exchangers
11. thermochemistry, heats of reaction, energy conservation in non-isothermal reactors, T-t profiles
12. deconstructing chemical accidents, runaway reactors, adiabatic flames

Contribution of course to meeting the professional component

This course introduces chemical processes and their quantitative analysis using macroscopic mass and energy balances. Simple design problems are drawn from the processing industry and current events. Industrial accidents and chemical safety are illustrated.

Relationship of course to undergraduate degree program objectives and outcomes

This course is a key component of the initial building block in the chemical engineering curriculum. It introduces quantitative engineering analysis and design using conservation laws and real fluid properties.

Textbook(s) and/or other required material

- Duncan T.M. and Reimer J.A. *Chemical Engineering Design and Analysis: An Introduction;* second edition draft, 2016.

Reference Texts (on reserve in the Chemistry Library)

- Denn, Morton M *Chemical Engineering, An Introduction* Cambridge University Press, 2011.
- Murphy, Regina *Introduction to Chemical Processes* McGraw Hill, 2007.
- Himmelblau; Riggs *Basic Principles and Calculations in Chemical Engineering*, 7^{th} ed. Prentice-Hall: Englewood Cliffs, NJ, 2004.
- Felder; Rousseau *Elementary Principles of Chemical Processes*, 3^{rd} ed.; John Wiley and Sons, Inc., 2000.

Course Hours and Location:
Lecture
MWF 8:10-9AM, 120 Latimer Hall
Sections
101; Mon 11-12PM, 385 LeConte
102; Wed 12-1PM, 247 Cory
104; Wed 2-3PM, 102 Wurster
106; Fri 9-10AM | 310 Hearst Mining
107; Fri 10-11AM | 3113 Etcheverry
108; Fri 11-12PM | 105 Latimer

Assessment of student progress toward course objectives

- Weekly homework-problem assignments
- Participation in class and discussion sections
- Design projects
- Multiple one-hour mid-term examinations (Sept 24 and Nov 2)
- A final examination. FINAL EXAM GROUP 4 Monday December 12, 7-10 PM

Course Context

Three weekly lectures will be used to describe the underlying principles of the course. Weekly discussion sections will consist of problem-solving sessions, directed study, and group design work. This course will stress both theory and practical calculations: weekly homework and design projects emphasize the latter, quizzes and exams the former. All officers of the class will be available weekly during office hours. Attendance in lecture is mandatory. Latecomers are not welcome. There will be no eating or drinking during lectures.

Course Grading

Grades are based upon subjective evaluations of tests (3), homework, design projects (2), quizzes, and **course participation (call and response)**. An *approximate* breakdown of the weight of these assignments toward your final grade is: 10% homework, 15% design projects, 25% midterm exams, 25% final exam, 15% quizzes, and 10% course participation. In general, recognition of the course fundamentals in contexts completely unfamiliar to the student results in a letter grade of “A”; recognition of course fundamentals only in contexts similar to course materials will result in a letter grade of “C”. Mastery of all concepts at the most elementary level, and their recognition in a *few* previously unfamiliar situations, will earn the students a “B” letter grade.

Note on academic dishonesty

It is considered academically dishonest to turn in work to be graded (homework, project, quiz, exam) that is not your own work, unless the assignment explicitly states otherwise. You may work with others in preparing homework and studying for exams, but the work you turn in must be the **product of your own thinking**. Academic dishonesty can result in no credit for an assignment or the course. It can also result in referral to UC Berkeley authorities for additional sanctions.