Chemical Thermodynamics and Staged Unit Operations

ChE 3316 ◆ Fall 2015

CLASS MEETINGS: TR 0930-1045 & T 1300-1350 in ChE 005.

INSTRUCTOR: G.M. Geise, Assistant Professor of Chemical Engineering

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Office Hours:
M 4:00-5:00pm
T 2:00-3:00pm
R 2:30-3:30pm
By Appointment

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Office Hours:
M 1:00-3:00pm
W 4:00-6:00pm

COURSE DESCRIPTION:

What is this course really about?

Two grand challenges facing society in the coming years are to provide clean water and energy resources to a worldwide population that desperately needs both. Chemical engineers are well poised to address such challenges, and chemical thermodynamics plays a critical role in predicting how physical systems in separation and energy-related processes respond to operating variables such as temperature and/or pressure. Additionally, electrochemical thermodynamics plays a critical role in predicting the behavior of emerging battery and water purification technologies. As phase and chemical equilibrium thermodynamics is a key starting point for understanding the performance of a variety of classic staged unit operations including distillation, extraction, and other common chemical processing technologies that are used in industries ranging from petrochemical to biopharmaceutical, it is a topic that is central to solving many challenges facing our world today. This course will highlight the power of thermodynamics as a tool that chemical engineers use to solve complicated real-world problems. In addition to covering classic chemical engineering topics, we will also use state-of-the-art process simulation software to model and further understand thermodynamics and staged unit operations.

Credit Hours: 4
Prerequisites: ChE 2202 and 2215, or equivalent. Corequisite: ChE 3321.

COURSE OBJECTIVES:

What are we going to learn this semester?

By the end of this course, you will be able to:

> Describe the role of thermodynamics in staged unit operations
> Recognize the value of chemical thermodynamics and staged unit operations in relevant real-world problems and/or processes
> Develop skills for computing (or otherwise determining) thermodynamic properties related to phase and chemical equilibria
> Apply thermodynamic models to describe physical properties and phenomena
> Combine material balances and phase equilibrium information to determine design-related parameters for staged unit operations
> Use the Aspen process simulator to obtain property values, simulate thermodynamic equilibrium, and model staged unit operations

FINDING INFORMATION:

No one textbook covers all of the material relevant to this course, so we will pull primarily on material from two textbooks:

Sandler, *Chemical, Biochemical, and Engineering Thermodynamics,* 4^{th} ed., 2006 (ISBN: 0471661740)

Wankat, *Separation Process Engineering*, 3^{rd} ed., 2012 (ISBN: 0131382276)

Additionally, we will use other classic chemical engineering resources available either through the course Collab site or the U.Va. library.

Practicing chemical engineers routinely draw information from a variety of sources (many of which are available electronically). You are encouraged to explore these sources of information to identify additional resources outside of those that are recommended.

HOW TO SUCCEED:

Success with Excellence

Each of you is capable of being successful in this course. Given differences in prior experience, however, expect this course to require different amounts of invested time and effort (from student to student) to learn the material and achieve the course objectives. A few suggestions for success are provided below:

Complete the assigned reading before class (really!). Familiarizing yourself with the material ahead of class will put you in a better position to discuss the material and to ask questions that will help you and your colleagues during class. The assigned reading will compliment our discussions during class and help you to increase the depth of your understanding. Furthermore, completing the reading assignment helps to get everyone to a similar starting point before class.

Come to class (on time!). Class time gives us the opportunity to focus more deeply on learning through lecture, questions, and discussion. We will build on material from the reading assignment and also will have the opportunity for discussion during class time.

Engage during class. Writing notes and participating in discussions during class can help you summarize and ultimately learn. Taking notes on questions that you have along the way (particularly while completing reading assignments) will help you to remember questions to ask during class and/or office hours, and this practice will help you evaluate your learning progress.

(Perfect) practice makes perfect. Participating in class discussions, working diligently on homework practice questions and problems, and discussing your learning progress with others inside and outside of class will help facilitate your learning process. Working on homework with other students can be helpful and is encouraged, but it is most helpful when you have worked on all of the homework problems *on your own* prior to discussing the problems with your classmates. Discussing homework assignments with other students who are enrolled in the course is acceptable and encouraged, but directly copying homework solutions from other students or other sources will undermine your learning process and is orthogonal to professional best practices and ethics.

Seek help (early and often!). Come to office hours to discuss aspects of the course. Be prepared to engage in a discussion, e.g., do not expect us to tell you explicitly how to do the homework problems. These discussions help us to understand how to better facilitate learning within the course.

Don't fall behind. The material in this course builds on itself. If you feel that you are slipping behind in the course, seek help immediately. Staying caught up with the class likely will make the experience more enjoyable for you in general, and it will promote deeper learning.

COURSE SCHEDULE:

Where are we going to go this semester?

We are going to explore the following questions during the semester:

- What is equilibrium, and how do we define it? (week 1)
- How do chemical engineers think about, calculate, and visually represent information about the phases of mixtures? (week 2)
- How can I use phase changes to do a separation, and why does it work? (weeks 2-3)
- In what ways can I manipulate systems and/or equipment to modify the characteristics of a separation? (weeks 3-4)
- How do I answer these questions if my system contains more than two components? (week 5)
- What happens to the phases of mixtures when molecules interact within a system? (weeks 5-6)
- What special challenges/opportunities exist for separating non-ideal mixtures of components? (weeks 6-7)
- What are the components of a distillation system, and how would I start to think about designing such a system? (week 8)
- How is opening a carbonated beverage can related to reducing CO_2 content in industrial flue gas? (week 9)
- Oil and water don't mix; how do chemical engineers describe this phenomenon, and how can I use this phenomenon to my advantage in separations? (weeks 9-10)
- How do chemical engineers think about processing involving solids and liquids? (week 11)
- How can chemical reaction equilibrium concepts be extended to describe interactions between gases and solid surfaces? (weeks 12-13)
- How do chemical engineers approach complex systems involving multiple reactions, and how can adjusting the operating conditions of a reactor optimize these systems? (week 14)
- What happens if multiple phases and reactions occur within the same system? (week 15)
- How are batteries related to turbines, heat engines, and rust? (week 15)
- How do ionic interactions provide opportunities and challenges for separations? (week 16)

EVALUATING PROGRESS:

Your progress throughout the course will be evaluated and assessed using different techniques as described below.

Progress checks / participation. Throughout the course, we will have occasional progress checks that may be administered as Collab 'quiz' questions or during class. These activities will be designed to help you assess your progress throughout the course. In most cases, these assessments will be graded for thoughtful completion (i.e., reasonable answers), but in some cases they may be graded for correctness. (5%)

Homework questions and problems. Weekly sets of questions and problems will provide you with a focused opportunity to think about and practice concepts and skills that we discuss during class that week. In addition to thinking more deeply about the concepts that are central to the course, you will be challenged to make use of external software or informational resources to complete some of the homework. Additionally, each assignment will contain a 'choose your own adventure' prompt (listed last on the assignment sheet) that will give you an opportunity to explore or discuss an aspect of the course material. Your responses to these prompts will be shared with your classmates via a Collab Forum. (15%)

Aspen projects. During the semester, you will learn to use the Aspen Plus simulation software package to simulate unit operations via a series of team projects designed to be a guided introduction to using the software. (14%)

Examinations. Three examinations (two evening and one in-class) will be used to assess your learning progress toward achieving many of the course learning objectives. The examinations will assess both conceptual and problem-solving skills learned during a period of the course that will span roughly 3 homework question and problem sets. (Exams 1 and 2: 34% & Exam 3: 12%)

Schedule:

Exam 1: *6:30-8:30pm on Tuesday, Sep. 22, 2015 (ChE 005)*
Exam 2: *6:30-8:30pm on Wednesday, Oct. 21, 2015 (MEC 205)*
Exam 3: *Tuesday, November 10, 2015 @ 9:30am in ChE 005 (in class)*

Final examination. On the comprehensive final examination, you will be challenged with a series of questions and problems that will assess your ability to explain concepts, justify choices, analyze physical systems, and solve problems using what you have learned throughout the course. (20%)

Schedule: *December 18, 2015 from 2:00-5:00pm in ChE 005*

HONOR SYSTEM: From the SEAS Honor Committee: "The School of Engineering and Applied Sciences relies upon and cherishes its community of trust. We firmly endorse, uphold, and embrace the University's Honor principle that students will not lie, cheat, or steal, nor shall they tolerate those who do. We recognize that even one honor infraction can destroy an exemplary reputation that has taken years to build. Acting in a manner consistent with the principles of honor will benefit every member of the community both while enrolled in the Engineering School and in the future."

Members of this course are also expected to abide by the Code of Ethics of the American Institute of Chemical Engineers (AIChE): http://www.aiche.org/about/code-ethics

Do your best to make today and every day a great day
for the University of Virginia.