BioE 332, Thermodynamics
Spring 2024

Meeting time
10:00 am -10:50 am M, W, F

Location
BRC 284

Instructor
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TAs
Daniel Haller (djh18@rice.edu)
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Office Hours
By appointment

Course description
BIOE 332 is a mathematically rigorous coverage of the fundamentals of engineering thermodynamics with applications to contemporary bioengineering problems. Topics covered include: properties of ideal and real gases, the first law of thermodynamics, thermochemistry, enthalpy and heat capacity, the second law of thermodynamics, Carnot and heat engines, the third law of thermodynamics, Helmholtz and Gibbs Free Energies, chemical potential and colligative properties, phase equilibrium, Clapeyron Equation, liquid solutions, Gibbs-Duhem Relation, activity and non-ideal mixing, solid-liquid solutions, chemical equilibrium, the hydrophobic effect, ligand-protein interactions, protein-DNA binding, transcriptional regulation, protein folding, nucleic acid folding, nucleic acid hybridization, mRNA:ribosome binding and translation. BioE 332 is designed for junior students; it builds on BioE 252 and serves as foundation for BioE 420.

Prerequisites
Math 212, BioE 252

Concepts and critical skills implied by prerequisites that students must know to take this course:
Conservation principles; chemical reactions; differential and integral calculus; partial derivatives; basic molecular biology, numerical methods.

Professional Component Content
Engineering (3 hrs)

Textbook
"Introduction to Chemical Engineering Thermodynamics". 8th edition. J.M. Smith, H.C. Van Ness, M.M. Abbott, M.T. Swihart. McGraw-Hill. ISBN 978-1-259-69652-7.

Supplemental Texts (not required)
"Physical Chemistry". 7th edition. P. Atkins, J. DePaula. W.H. Freeman and Company. New York. ISBN-0-7167-3539-3

"Physical Chemistry for the Biosciences". R. Chang. University Science Books. ISBN 10:1-8951389-33-5

"A genetic switch: Phage Lambda revisited". 3rd edition. Mark Ptashne. ISBN-10: 0879697164

Supplemental websites (not required)

Nelson, Keith A., and Moungi Bawendi. 5.60 Thermodynamics, Spring 2008. (Massachusetts Institute of Technology: MIT OpenCourseWare), http://ocw.mit.edu License: Creative Commons BY-NC-SA

Colorado University Learn ChemE. Department of Chemical and Biological Engineering. http://www.learncheme.com.

Course Materials
1. The course syllabus will be posted on Esther and the Canvas course webpage.

2. Lecture notes, assigned readings, supplemental materials, problem sets, problem set solutions, quizzes, quiz solutions, graded materials, and grades will be posted on Canvas.

3. The course content is adapted from Smith and Van Ness, Atkins, Colorado Learn ChemE, and MIT OpenCourseware among other sources, all of which are attributed.

Attendance Policy
Students are expected to attend all classes. If you must miss a class, please provide 48 hours prior written notice to the instructor. We understand that last minute things come up from time to time, and will not penalize you for missing a small number of classes without prior notice.

Recorded class meetings
All class meetings will be recorded and posted to Canvas.

Disabilities
Accommodations are made for students with disabilities.

Grading
Problem sets 50%
Quizzes 50%

A+ = 97+
A = 92-96
A- = 90-91
B+ = 88-99
B = 82-87
B- = 80-81, etc.
Pass = 60+

Problem sets
Nine problem sets will be assigned. Problem sets will be released on Canvas Fridays at 11:00 am and due the following Friday on Canvas at 10:00 am. The final problem set will be due Wednesday the last week of class. Problem set solutions must be uploaded as PDFs on Canvas. Please practice uploading PDFs to Canvas prior to the due date of the first problem set in order to avoid technical problems in uploading your problem set on the due date.

Problem set solutions will generalhy be released on Canvas Fridays at 11:00 am to facilitate studying for quizzes, which are generally given the following Monday. **Therefore, no late problem sets can be accepted.** The lowest grade from problem sets #1-8 will be automatically dropped to account for any emergencies or other situations that may prevent students from submitting problem sets on time. Problem Set #9 will not be dropped.

Currently-enrolled students are encouraged to work with other currently-enrolled students on problem sets. However, all answers must be your own. Students may not copy one another’s answers. Students may not use any source of solutions to problem set problems. Examples of sources of solutions include but are not limited to: solutions manuals, online repositories of problems/solutions, hard copies of problems and solutions, websites wherein a third party aids in answering a problem, apps that enable people to communicate problems or their solutions to one another, or artificial intelligence applications. If you have any question about whether a resource you aim to use on a problem set is allowed, you must email the instructor and await approval prior to using the resource.

Artificial intelligence
The use of artificial intelligence on any graded assignment (problem sets, quizzes) is completely forbidden.

Recitation sessions
There will be a TA recitation session each evening prior to problem set due dates (usually Thursdays) at 7:00 pm prior to problem set due dates. Recitation sessions will be in BRC 284 (pending confirmation), simulcast via Zoom, and recorded and posted to Canvas the following day. Students are encouraged to attend the recitation session and ask questions about the problem set. The TA will help guide you in the right direction but will not provide answers to problem set problems.

Quizzes
Nine in-class quizzes will be given throughout the semester. Quizzes will be administered on paper. Quizzes will cover material on the previous week's problem set. Unless excused in writing by the instructor at least 1 day ahead of time, students must be physically present in class while taking the quiz in order to receive credit.

The lowest grade on quizzes 1-8 will be dropped. The dropped quiz accounts for illness, challenges due to factors outside of the class, emergencies, and so on. Quiz #9 will not be dropped. No quiz make-ups will be given unless approved by the instructor due to extraordinary, well-documented circumstances.

Students may not work with others on quizzes. You may only use pencil/pen, paper, and calculators.
You may not use the internet, email, books, notes, printouts or any other type of reference material during quizzes. You may not communicate with anyone other than the proctor, nor use any type of communication system during quizzes. If you have any question about whether something you will do during a quiz is acceptable, you must receive approval from the instructor or proctor prior to doing it.

Quiz solutions will be available on Canvas shortly after the quiz is due.

Honor code
Students must follow the Rice Honor Code on all submitted work. Any suspected infraction will be reported to the Rice Honor Council.

How to be successful in BioE332
There are a large amount of new concepts in thermodynamics. You must take initiative in learning the material. The only way to do this is to read the textbook and posted course materials, watch the assigned online lectures and screencasts, do the problem sets, and attend the help sessions and lectures. We are here to help you learn the material, but you should also rely on one another and the materials available to you.

Course objectives
Students should learn:

1. To understand the Four Laws of Thermodynamics and the related concepts of Enthalpy, Entropy and Free Energy and be able to quantitatively evaluate work and heat transactions in thermodynamic processes. [Course outcomes 1-16]

2. To understand and be able to quantitatively predict phase, chemical and macromolecular binding equilibria [Course outcomes 9-15]

3. To understand how thermodynamic considerations influence design in bioengineering. [Course outcome 16]

Course outcomes
Students completing the course should be able to:

1. Calculate state variables before and after perturbations to ideal, Van der Walls, and Virial gases.

2. Understand how energy flows in compression and expansion work and be able to calculate work-related energies for reversible and irreversible processes.

3. Apply thermodynamic laws and relationships to calculate the values of heat, work flow and internal energy and enthalpy change during various thermodynamic processes.

4. Understand how enthalpy and entropy drive processes in biological settings and apply this to the engineering of biocompatible devices.

5. Calculate entropy, Gibbs and Hemholtz Energy changes in thermodynamic processes.

6. Calculate thermodynamic variables and system states in isenthalpic processes.

7. Expand a state function in terms of its partial derivatives and understand how to relate these derivatives to thermodynamic quantities.

8. Use van der Waals equation to model and predict thermodynamic properties of real substances.

9. Understand the nature of the reaction potential and apply it to the prediction of equilibrium states in thermodynamic systems.

10. Apply equilibrium measurement data to the calculation of enthalpy and entropy changes during thermodynamic processes.

11. Understand the nature of criticality and phase equilibria in thermodynamic systems.

12. Derive relationships between thermodynamic variables using Maxwell relations.

13. Use partial molar quantities and the Gibbs-Duhem relation to compute partial molar thermodynamic properties in multi-component mixtures.

14. Use thermodynamic properties to understand protein folding, protein-ligand binding, protein-protein interactions, protein-DNA binding, transcriptional regulation, and translational regulation.

15. Design nucleic acid sequences to program gene regulation or a metabolic process.

15\. Use thermodynamics in Bioengineering applications.