

# CHM 431 - Physical Chemistry I

## Course Syllabus

### Fall 2023

1. Instructor: Dr. David L. Freeman  
Phone: 874-5093  
Office: Beaupre 474 C  
e-mail:dfreeman@uri.edu  
Office Hours: MWF 10.
  2. Scheduling: MWF 9, Beaupre 105 A
  3. Text: *Thermodynamics, Statistical Thermodynamics and Kinetics* by Thomas Engel and Philip Reid, Fourth Edition, Prentice Hall, 2019
  4. Prerequisites: CHM 192 or CHM 112, MTH 142, PHY 112 or 204. Knowledge of the material in these courses will be assumed.
  5. WWW course home page: <http://www.chm.uri.edu/courses/?chm431&1>
  6. Course requirements:
    - (a) Hour Exams (Wednesday, September 27; Friday, October 20; Wednesday, November 15; Friday, December 8 - All hour exam dates subject to change.) 400
    - (b) Final exam (Monday, December 18, 11:30 AM -1:30 PM) 200
    - (c) Total 600
- Grades will be determined on a curve. Incompletes will be given only for documented medical reasons. In the case of an exam missed for a valid medical reason, discuss options with the instructor. If an exam date is canceled owing to weather or any other reason, the exam will be given on the next date the class meets.
7. Viral Illness Precautions Statement: The University is committed to delivering its educational mission while protecting the health and safety of our community. Students

who are experiencing symptoms of viral illness should NOT go to class/work. Those who test positive for COVID-19 should follow the isolation guidelines from the Rhode Island Department of Health and CDC.

If you are unable to attend class, please notify me prior to the start of class at 401-874-5093 or [dfreeman@uri.edu](mailto:dfreeman@uri.edu).

8. Excused Absences: Absences due to serious illness or traumatic loss, religious observances, or participation in a university sanctioned event are considered excused absences. Students are responsible for work missed during an excused absence but will not be penalized by grading or assignment/exam make-up policies. Students should notify faculty in advance of absences due to religious observance or university-sanction events, and as soon as possible for other absences See University Manual sections 8.51.11-8.51.14 for details.
9. Mental Health and Wellness: We understand that college comes with challenges and stress associated with your courses, job/family responsibilities and personal life. URI offers students a range of services to support your mental health and wellbeing, including the URI Counseling Center, MySSP (Student Support Program) App, the Wellness Resource Center, and Well-being Coaching.
10. Land Acknowledgement: The University of Rhode Island land acknowledgment is a statement written by members of the University community in close partnership with members of the Narragansett Tribe. The statement recognizes and pays tribute to the people who lived on and stewarded the land on which the University now resides. The statement seeks to show gratitude and respect to Indigenous people and cultures and build community with the Narragansett Nation and other Native American tribes.

#### University of Rhode Island Land Acknowledgment

The University of Rhode Island occupies the traditional stomping ground of the Narragansett Nation and the Niantic People. We honor and respect the enduring and continuing relationship between the Indigenous people and this land by teaching and learning more about their history and present-day communities, and by becoming stewards of the land we, too, inhabit.

11. Anti-Bias Syllabus Statement: We respect the rights and dignity of each individual and group. We reject prejudice and intolerance, and we work to understand differences. We believe that equity and inclusion are critical components for campus community members to thrive. If you are a target or a witness of a bias incident, you are encouraged to submit a report to the URI Bias Response Team at [www.uri.edu/brt](http://www.uri.edu/brt). There you will also find people and resources to help.
12. Disability, Access, and Inclusion Services for Students Statement: Your access in this course is important. Please send me your Disability, Access, and Inclusion (DAI)

accommodation letter early in the semester so that we have adequate time to discuss and arrange your approved academic accommodations. If you have not yet established services through DAI, please contact them to engage in a confidential conversation about the process for requesting reasonable accommodations in the classroom. DAI can be reached by calling: 401-874-2098, visiting: [web.uri.edu/disability](http://web.uri.edu/disability), or emailing: [dai@etal.uri.edu](mailto:dai@etal.uri.edu). We are available to meet with students enrolled in Kingston as well as Providence courses.

13. Academic Enhancement Center: The Academic Enhancement Center (AEC) offers face-to-face and online services to undergraduate students seeking academic support. Services are based out of Roosevelt Hall, the Carothers Library room LL004, and online. Peer tutoring is available for STEM & BUS-related courses through the Drop-In Center and small-group tutoring. The Writing Center peer consultants offer feedback focused on supporting undergraduate writers at any stage of a writing assignment. The UCS 160 course and one-to-one Academic Skills Consultations offer strategies for improving studying and test-taking skills. Complete details about each of these programs, up-to-date schedules, contact information, and self-service study resources are all available on the AEC website, [uri.edu/aec](http://uri.edu/aec).

All Academic Enhancement Center support services for Fall 2023 begin 9/11/23.  
Visit [uri.edu/aec](http://uri.edu/aec) for information about our AEC programs.

- STEM & BUS Tutoring helps undergraduate students navigate a variety of 100 and 200 level STEM & BUS courses through free peer tutoring in-person and online. Students can select occasional or weekly tutoring sessions through the TracCloud system or visit the Drop-In Center, located in the Carothers Library lower level room LL004. The TracCloud application is available through URI Microsoft 365 single sign-on and more detailed information and instructions can be found at [uri.edu/aec/tutoring](http://uri.edu/aec/tutoring).
- Academic Skills Development programs teach students to develop and apply metacognitive thinking strategies to improve their time management, problem solving and study skills. UCS 160: Success in Higher Education is a 1-credit course on planning and managing work and studying in college. UCS 161: Becoming a Self Directed Student teaches strategies for identifying and overcoming challenges in academic work and life. Academic Consultations are 1 to 1 in-person or online consultations that help students to directly address individual academic challenges. Students can schedule sessions with Peer Academic Consultants on TracCloud or with Dr. David Hayes on Starfish. Finally, Study Your Way to Success is a self-guided web portal connecting students to tips and strategies on studying and time management related topics. For information or help with scheduling, contact Dr. Hayes directly at [davidhayes@uri.edu](mailto:davidhayes@uri.edu)

- The Undergraduate Writing Center provides peer writing support to students in any class, at any stage of writing: from understanding an assignment and brainstorming ideas, to developing, organizing, and revising a draft. Writing consultations are available through: 1) 25- or 50-minute in-person appointments, 2) synchronous online appointments, and 3) asynchronous written feedback. Students can view availability and book online through URI Microsoft 365 single sign-on via the WCOOnline (Undergrad) app. For more information, visit [uri.edu/aec/writing](http://uri.edu/aec/writing).

14. Center for Career and Experiential Education: The Center for Career and Experiential Education (CCEE) supports undergraduate students with career preparation through one-on-one advising, 24-7 online resources, career education courses, and career events that prepare you for life after graduation and connect you with employers and community partners. Your Career Education Specialist (CES) is available to meet with you all year long, as early as your first-year, both in-person and virtually, to assist with exploring your career options, resume and cover letter writing, interview preparation, job and internship search, and more. We use Handshake to connect you to on and off campus jobs and internships and RhodyServes to connect you with volunteer opportunities in RI. Our team on the first floor of Roosevelt Hall can help you learn how to use Handshake effectively to find amazing opportunities. For more information or to meet with a CES, go to [uri.edu/career](http://uri.edu/career).

15. Rhody Outpost Basic Needs Pantry: Food insecurity affects up to 30% of college students. That means you might not have enough food to get through a day or week, you don't have money to purchase groceries or personal products, or you are primarily eating foods that don't provide a lot of nutrition because they're all you can afford. This can all impact your academic success.

Rhody Outpost provides URI students who are food insecure with emergency food services and resources. The Outpost is housed at the Dining Services Warehouse at 10 Tootell Road, between Flagg Road and West Alumni Avenue. We are open every Friday from 3-5:30. Any student in need is welcome to visit the Outpost after filling out a brief request form.

If you have questions about food or housing insecurity, contact Barbara Sweeney, Coordinator of Food Security Outreach, at [barbara\\_sweeney@uri.edu](mailto:barbara_sweeney@uri.edu), or 401-874-5633. We want to help all students succeed and make URI a place with #NoRamHungry.

16. Overview and Course Goals:

Physical chemistry is the study of the application of the principles of physics to chemical phenomena. In a simple sense, we can think of physical chemistry as subdivided into three topics: thermodynamics, quantum mechanics and kinetics. In reality, these subtopics are interrelated, and it is a goal of both CHM 431 and CHM 432 for you to appreciate the relations.

Physical chemistry has the reputation of being a hard course. It is my feeling that the difficulties faced by third year students trying to learn physical chemistry arise from the large set of topics that must be mastered. Additionally, many of the topics that are covered are inherently abstract. This abstraction of chemical phenomena is not easy, and a major course goal for this year is to understand how the laws of physics enable us to understand the principles of chemistry in an abstract way.

Although physical chemistry is difficult, there is a way to be successful in this course. It is imperative that you do homework. Problem sets will be posted about once a week, and the homework problems will be representative of the kinds of questions you will be given on the examinations. Solutions to the problem sets will be posted before each quiz. It is important that the homework be completed before the solutions are posted for you to gain adequate practice with the material. Understanding a solution to a problem is far less difficult than the initiation of a solution to a problem. You will be asked to initiate solutions on examinations.

This semester we will be concerned with the principles that govern the macroscopic behavior of chemical systems. These principles are contained in the laws of thermodynamics. A major goal for CHM 431 is to understand the three laws of thermodynamics and how to apply the laws to chemical systems.

The thermodynamic laws we shall learn are only valid for systems at equilibrium. The thermodynamic laws provide the basis for the rationalization of equilibrium phenomena, including both phase and chemical equilibria. Understanding the thermodynamic basis of equilibrium is another course goal.

17. The CHM 431 Web page:

In this course all problem sets, problem set solutions, quiz solutions and final exam solutions are to be distributed on the course web page. No paper copies of the problem sets are to be distributed. The URL of our course web page is

<http://www.chm.uri.edu/courses/?chm431&1> . It is strongly suggested that you link to our web page to obtain the first problem set as soon as possible.

It is expected that for most of you, success in this course will require some level of help beyond classroom instruction. Because some of you may find it difficult to come to the scheduled office hours, we have installed as part of our course web pages, a page that can be used to submit questions. Questions are submitted by anyone in the class by filling out a form on the web page, and answers are distributed either to the entire class or only to the person asking the question. If the entire class is to receive a copy of the question and answer, the question is treated as anonymous; i.e. the person who asks the question is never identified. In fact, it is possible to submit a question so that even the instructor does not know who submitted the question. Anonymous questions and responses by the instructor are distributed automatically using Sakai. With ordinary electronic mail, there is a private correspondence between the student and instructor.

By using the web page, the entire class has an opportunity to learn from the questions submitted.

The use of the web page does not preclude personal interaction between any of you and the course instructor. Dr. Freeman has regular office hours, and you are all encouraged to make use of these hours. Alternate meeting times can be arranged by appointment. Additionally, you can contact Dr. Freeman by e-mail or telephone. The e-mail address and phone number for Dr. Freeman is given on the first page of this syllabus.

Any student in CHM 431 can submit questions and comments to Dr. Freeman. Submission of such comments or questions must be made using the WWW home page for this course. The address (URL) of our home page is

<http://www.chm.uri.edu/courses/?chm431&1> . To submit a question to the list, you must click on the highlighted text that says “submit a question to the CHM 431 list.” As an example of how to use the list, suppose a student in our class, Ms. Benzene Ring, wonders, “Is work a path or a state function?” (If you don’t know what this means, don’t worry. You will understand the question early in the semester). To obtain an answer to her question, Ms. Ring links her web browser (e.g. Firefox, Safari or Google Chrome) to <http://www.chm.uri.edu/courses/?chm431&1>, and she then clicks on the text linking her to the page for questions (i.e. the highlighted text that says “submit a question to the CHM 431 list”). Ms. Ring then optionally can enter her e-mail address in the appropriate box and specify (this is not optional) whether she wants her question to be answered to the entire CHM 431 class or to her alone. Ms. Ring then types in the large box

Is work a path or a state function?

Ms. Ring then clicks the “send” button. Ms. Ring’s question is received by Dr. Freeman. Dr. Freeman then sends an e-mail message to the whole list that might be

Subject: work

The question is: The question is: Is work a path or a state function?

Answer: Work is a path function.

Now Ms. Ring and the entire class have an answer to her question.

If the answer to the question can be sent to the entire list, the answer will not indicate who asked the question. If Ms Ring wants to ask the question with full anonymity so that even Dr. Freeman has no idea who asked the question, the e-mail portion of the form can be left blank. Of course, if the e-mail section of the form is blank, the answer must be sent to the list and not just to the sender.

Because many questions may contain mathematical formulas, we need a notation to communicate the special symbols used in the course. To avoid confusion, it is most useful if we agree on the same set of symbols. The symbols that follow are taken from a language called  $\text{\LaTeX}$ .  $\text{\LaTeX}$  is a language that is frequently used to prepare scientific documents, and  $\text{\LaTeX}$  can be used to translate special symbols into simple

text characters. By learning L<sup>A</sup>T<sub>E</sub>X notation, you will learn a widely used method to communicate mathematical symbols via e-mail. The instructor plans to use these symbols in answering your questions, and it is asked that you use the same symbols in posing questions. The most important symbols are the following:

- (a) Greek letters are represented by \ followed by the name of the letter. For example  $\alpha$  is typed `\alpha`,  $\beta$  is typed `\beta`, and so on. A Greek letter is made upper case by making the first letter of its name upper case. For example, the letter  $\Delta$  is typed `\Delta`.
- (b) Subscripts are represented by `_{}`  where the brackets contain the subscripts. For example,  $\mu_{ij}$  is typed `\mu_{ij}`.
- (c) Superscripts are represented by `{}` where the brackets contain the superscripts. For example,  $\beta^{12}$  is typed `\beta{12}`.
- (d) Infinity ( $\infty$ ), is typed `\infty`.
- (e) The integral sign  $\int$  is typed `\int`. The limits on a definite integral are included by introducing subscripts and superscripts. As an example  $\int_0^\infty e^{-x^2} dx$  is typed `\int_{0}{\infty} e^{-x^2} dx`.
- (f) The partial derivative symbol  $\partial$  is typed `\partial`.
- (g) The summation sign  $\sum$  is typed `\sum`. The lower and upper limits of summation are included as subscripts and superscripts. As an example  $\sum_{n=0}^\infty 1/n^2$  is typed `\sum_{n=0}{\infty} 1/n^2`.
- (h) Square roots  $\sqrt{a+b}$  are typed `\sqrt{a+b}`.
- (i) The arrow in chemical reactions  $\rightarrow$  is typed `--->`. For example  $C+O_2 \rightarrow CO_2$  is typed `C + O_2 ---> CO_2`.

Let us now look at another example of a question submitted using the web. In this case, Ms. Ring has a question requiring an equation. This might be a real question. If you don't understand the context, don't worry. You will understand the details of the question later in the course. Suppose Ms. Ring wants to ask

“In deriving the expression for the phase equilibrium line between solid and liquid, when evaluating the integral expression

$$p_2 - p_1 = \int_{T_1}^{T_2} \frac{\Delta H}{T \Delta V} dT$$

the ratio of  $\Delta H$  to  $\Delta V$  is taken outside the integral. What is the justification for this?”

To submit the question, Ms. Ring uses her web browser to attach to <http://www.chm.uri.edu/courses/?chm431&1>, clicks on the line that says, “submit a question to the CHM 431 list,” and then Ms. Ring enters the information requested

by the form. If Ms. Ring wishes to remain anonymous, Ms. Ring leaves the e-mail box blank. Ms. Ring then types into the large box  
In deriving the expression for the phase equilibrium line between solid and liquid, when evaluating the integral expression  
$$p_2 - p_1 = \int_{T_1}^{T_2} \frac{\Delta H}{T} \frac{dT}{\Delta V}$$
the ratio of  $\Delta H$  to  $\Delta V$  is taken outside the integral. What is the justification for this?  
and clicks on the submit button. Ms. Ring's question is received by Dr. Freeman. The answer will be sent either to Ms. Ring alone, or preferably to the entire class if the appropriate box is checked. Dr. Freeman might reply

Subject: Phase equilibrium question

The question is: In deriving the expression for the phase equilibrium line between solid and liquid, when evaluating the integral expression  
$$p_2 - p_1 = \int_{T_1}^{T_2} \frac{\Delta H}{T} \frac{dT}{\Delta V}$$
the ratio of  $\Delta H$  to  $\Delta V$  is taken outside the integral. What is the justification for this?

The answer is: For solids and liquids the ratio  $\Delta H / \Delta V$  is only weakly dependent on temperature. The ratio, then, can be taken outside the integral to a good approximation.

18. Course outline:

<u>Topic</u>	<u>Book Chapter</u>
1. Energy and Work	
2. Thermodynamic Systems and the Ideal Gas Law	1
3. Heat, Work and the First Law	2
4. State Functions and Some Mathematics for Thermodynamics	3
5. Thermochemistry	4
6. The Second and Third Laws	5 (Skip Sec. 5.11-5.13)
7. The Free Energy Functions and Chemical Equilibrium	6, 5.11, 5.12
8. Real Fluids	7
9. Phase Transitions in One-component Systems	8
10. Ideal and Real Solutions	9
11. Electrolyte Solutions	10
12. Electrochemistry	11
16. Final Exam	Comprehensive