

WESTERN UNIVERSITY
DEPARTMENT OF CHEMISTRY
CHEM 2374A – Thermodynamics
COURSE OUTLINE 2021

Welcome to CHEM 2374A!

Instructor Dr. Styliani Conostas, ChB 071 (Lower ground floor)

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Lecture hours Monday, Wednesday, Friday 10:30-11:20 am, in NSC-1, face-to-face.

Office hours: Every Monday and Wednesday 4:00 pm-5:00 pm on zoom. Zoom connection details will be posted on owl.

Additional office hours every week is to be held by a Teaching Assistant (the dates and times will be released on owl).

Course website: <http://owl.uwo.ca/portal>

- All course material will be posted to OWL: <http://owl.uwo.ca>. This is the primary method by which information will be disseminated to all students in the class. Students are responsible to check OWL (<http://owl.uwo.ca>) on a regular basis for news and updates.

If students need assistance, they can seek support on the OWL Help page. Alternatively, they can contact the Western Technology Services Helpdesk. They can be contacted by phone at 519-661-3800 or ext. 83800.

Follow chemistry on Twitter: **@WesternuChem** and join the conversation.

Brief course description An introduction to classical thermodynamics. Topics to be covered include: Zeroth law of thermodynamics, first law of thermodynamics, enthalpy, entropy, second and third law of thermodynamics, Helmholtz and Gibbs energies, chemical potential, non-ideal gases, phase diagrams, ideal and real solutions, properties of ionizing solvents, electrolyte solutions, electrochemical cells.

Notice from the Registrar Unless you have either the prerequisites for this course or written special permission from your Dean to enroll in it, you will be removed from this course and it will be deleted from your record. This decision may not be appealed. You will receive no adjustment to your fees in the event that you are dropped from a course for failing to have the necessary prerequisites, which are (Chemistry 1301A/B and Chemistry 1302A/B with a minimum mark of

60% in each), (Chemistry 1301A/B and Integrated Science 1001X) with a minimum mark of 60% in each; Calculus 1000A/B, the former Calculus 1100A/B, or Calculus 1500A/B and 0.5 course from Applied Mathematics 1201A/B, Calculus 1301A/B, Calculus 1501A/B, Mathematics 1600A/B, Mathematics 1225A/B, Mathematics 1229A/B, with a minimum mark of 60% in each of the two 0.5 courses.

Anti-requisites: Chemistry 2214A/B.

Course Learning Outcomes

1. Knowledge of Scientific Principles: Be able to describe the fundamental scientific principles of thermodynamics and apply these principles in assignments, discussions on/off line and new problems.
2. Knowledge of Methods: Obtain problem-solving skills in physical chemistry by solving assignments, quizzes and on/off-line discussions and lecture material.
3. Application of Knowledge: Be able to apply the knowledge in order to predict and rationalize the physical and chemical properties of systems and the direction in which chemical and physical processes proceed.
4. Communication: Be able to prepare logical and concise written reports via training in quizzes and assignments.
5. Awareness of Knowledge Limits: Recognize assumptions and limitations in the scientific models and their possible impact on the results by training on case studies, lectures, assignments, quizzes.
6. Autonomy and Professional Capacity: (i) Be able to work productively and collaboratively as a team member by solving problems with other students. (ii) Evaluate the potential impact thermodynamics may have in society, health and environment.

Course Material

- Required Course Textbook for CHEM2374A : Physical Chemistry, by Peter Atkins, Julio de Paula, and James Keeler, **11th Edition**. This book may be also used in other courses such as CHEM3374A.

Excerpts from the book on the material covered in CHEM2374A, have been made available to the students via owl. **The material can be accessed in the ``Course Readings'' tab in the owl site of the course.**

Students can order through the [Book Store's](#) website and the books will be shipped directly to them, or can pick up in store (see our updated Safety Measures here: <https://bookstore.uwo.ca/safety-measures>). The bookstore has also an ebook version that the students can purchase through the Book Store's website.

<https://bookstore.uwo.ca/textbook>
search?campus=UWO&term=W2021A&courses%5B0%5D=001_UW/CHE2374A

- The book has an accompanying Student Solutions Manual, Atkins' Physical Chemistry, 11th Edition by P. Bolgar, H. Lloyd, A. North, V. Oleinikovas, S. Smith, J. Keeler, Oxford University Press. The manual is optional.
- Lecture notes, assignments, quizzes.

Course Evaluation

- **6 Assignments** : 0% The assignments will not be graded and are not to be submitted for assessment.
 - The assignments provide practice with the new concepts learned in the course. The instructor will provide the answers to the problems of the assignment when the assignment is released.
 - The assignment will be released at the beginning of the lectures that are covered, thus the problems are to be done gradually and be completed as the material progresses.
 - The assignments may be done with your peers. It is important to understand the solution – weaknesses in the understanding of the solutions will appear in the quizzes, midterms and final exams.
 - For the date of assignment release and the material covered please see table that follows.

- **5 Quizzes: 1 % each X 5 = 5%** of the course grade . The information about the quizzes follows:

What is the content of the quiz?

- Each quiz corresponds to the material of one assignment, besides the 6th assignment for which there is no quiz.
- The quiz is open book. You can use your notes during the quiz. However, it should be taken into consideration that if the time is spent to search the notes, no time will be left to complete the quiz.
- An equation sheet of all the material in the course will be posted on owl, but for the quizzes, you can create your own equation sheet and notes. Conversion of units need to be known.
- The instructor reserves the right to randomize or modify the questions of the quiz delivered to each student.
- Each quiz may have true/false questions, multiple choice questions or problems and problems to solve explicitly and upload on owl. The questions may or may not be similar to that of the corresponding assignment but the examinable material is the same.
- At the end of the examination the quiz answer of each student will be checked for correlations with the other students' responses.

Where?

- The quizzes will be done on-line on owl and they last for 15 min. The 15 min period will be pre-set on owl.

When?

- A student may start the quiz any time between 00:01 am to 23:59 on the day of the quiz. The time of the quiz will terminate in 15 min from the starting time. For example, if one starts the quiz at 11:05 am the time will end at the beginning of the 20th minute at 11:20, NOT WHEN THE 20th minute is completed (this is how owl manages the time).
- The day of the quiz the class will be shorter by 15 min in order for the students to have the opportunity to complete the quiz during the class time if they wish (recommended).

Missed quiz?

- If you miss a quiz, contact the TA of the course to provide the date of the missed quiz and the reason. If there is no valid reason to miss a quiz, a grade of zero will be assigned to the missed quiz.
 - If there is a valid reason to miss the quiz, then the weight will be transferred to the other quizzes or midterms. If ONE quiz is missed for a valid reason, then each of the remaining 4 quizzes will worth 1.25 %. If two or more quizzes are missed because of a valid reason their percentage will be transferred equally to the midterm exams. See details in section on ``Accommodation and Accessibility''
- **Mid-terms: 20% each X 2 = 40%** of the course grade.
 - The duration of each midterm is 50 min. and takes place **IN-CLASS**.
 - The dates and the examinable material of the midterms are presented in the table that follows.
 - In the midterm only the aid-sheet provided by the instructor and a non-programmable calculator are allowed.
 - **Final: 55 % of the course grade.**
 - The duration of the final exam will be 3 hours and the date will be determined by the registrar's office.
 - The exam will be cumulative.
 - During the exam only the aid-sheet provided by the instructor and a non-programmable calculator are allowed.

To pass the course, you must obtain a minimum of 50% in the average of the quizzes, midterms and final. **One should write both midterms and the final exam to pass the course.** Obtaining a good average grade in the quizzes and midterms is not sufficient to pass the course.

For accommodation due to illness or other serious reason see section on ``Accommodation and Accessibility''.

Tentative Lecture Schedule

Notes

1. In the schedule that follows, the due dates, the dates of the quizzes, midterms and posting of the assignments are firm. The schedule of lecture material is approximate only. The instructor reserves the right to re-arrange the order of the sub-topics if it is necessary for the flow of the course.
2. In the table below the assessments bearing marking are written in red boldface.
3. The quizzes are on the same material as the corresponding (same numbered) assignment.
4. In the table that follows, APK refers to Physical Chemistry, by Peter **Atkins**, Julio de Paula, and James **Keeler**, **11th Edition**. **The material can be accessed in the "Course Readings" tab in the owl site of the course.**

Date	Topics	Associated Readings	Assessment & Due Dates
Wednesday, September 8	Welcome back! Course Introduction	Course syllabus	
	UNIT 1 - FUNDAMENTALS AND EQUATIONS OF STATE		
Friday, September 10	<ul style="list-style-type: none"> • Applications of Thermodynamics • What is studied in thermodynamics? • Fundamental definitions (system, type of systems, state variable, state of the system) • Meaning of temperature 	APK: Focus 1, pp. 4-6	
Monday, September 13	<ul style="list-style-type: none"> • Meaning of pressure • Equation of State • Perfect (ideal) gas law • Mixture of gases 	APK: Focus 1, pp. 6-10	Assignment 1 is released to the students – it covers material from Sept. 10-Sept. 20 inclusive Assignments are not graded
Wednesday, September 15	<ul style="list-style-type: none"> • Deviation of the perfect gas from real gases • Compression factor 	APK: Focus 1, pp. 19-22	

	<ul style="list-style-type: none"> • Relation to intermolecular interactions • Van der Waals equation of state 		
Friday, September 17	<ul style="list-style-type: none"> • Explanation of the van der Waals isotherms • Law of corresponding states • Significance of the van der Waals equation 	APK: Focus 1, pp. 19-27	
Monday, September 20	<ul style="list-style-type: none"> • Other equations of state • Solution of problems 	APK: Focus 1, pp. 20, 21, 25	Solutions to Assignment 1 are released
	UNIT 2: FIRST LAW AND ENTHALPY		
Wednesday, September 22	<ul style="list-style-type: none"> • work, different types of work, volume-change work, surface tension work • heat • internal energy • molecular interpretation of internal energy 	APK: Focus 2, pp. 33-38	QUIZ 1 – Covers the same material as Assignment 1, i.e. Sept. 10-Sept. 20, inclusive
Friday, September 24	<ul style="list-style-type: none"> • Heat and work are not state functions • First law of thermodynamics • Reversible vs irreversible processes 	APK: Focus 2, pp. 38-42	Assignment 2 is released – it covers material from Sept. 22-Oct. 1, inclusive
Monday, September 27	<ul style="list-style-type: none"> • Estimating work, heat internal energy for Isothermal and Isobaric processes • Maximum work 	APK: Focus 2, pp. 38-42	
Wednesday, September 29	<ul style="list-style-type: none"> • Heat Capacity • Enthalpy 	APK: Focus 2, pp. 42-45; 46-50	
Friday, October 1	<ul style="list-style-type: none"> • Thermochemistry 	APK: Focus 2, pp. 51-58	Solutions to Assignment 2 are released
Monday, October 4	<ul style="list-style-type: none"> • State function and exact differentials 	APK: Focus 2, pp. 59-63	QUIZ 2 Covers the same

	<ul style="list-style-type: none"> • Partial derivatives • Examples 		material as Assignment 2, i.e. Sept. 22-Oct. 1st, inclusive
	UNIT 3: ENTROPY AND THE 2nd LAW; 3rd LAW		
Wednesday, October 6			MIDTERM #1 IN-CLASS Duration: 45 min; starts at 10:35 am, ends at 11:20 am. Examinable material is from Sept. 8 to Oct 1, inclusive
Friday, October 8	<ul style="list-style-type: none"> • Thermodynamic and Statistical Definitions of Entropy • Second Law of thermodynamics 	APK: Focus 3, pp. 77-82	Assignment 3 is released. it covers material from Oct. 4-Oct. 15, inclusive
Monday, October 11	Thanksgiving		
Wednesday, October 13	<ul style="list-style-type: none"> • Estimation of entropy changes 	APK: Focus 3, pp. 88-91	
Friday, October 15	<ul style="list-style-type: none"> • Temperature dependence of entropy changes • Third law 	APK: Focus 3, pp. 92-96	Solutions to Assignment 3 are released
	UNIT 4: FREE ENERGIES AND CHEMICAL POTENTIAL		
Monday, October 18	Helmholtz and Gibbs free energy	APK: Focus 3, pp. 97-100	QUIZ 3 - Covers the same material as Assignment

			<p>3, i.e. Oct. 4-Oct. 15, inclusive</p> <p>Assignment 4 released. It covers Oct. 18-Oct. 27, inclusive.</p>
Wednesday, October 20	Changes in the Gibbs free energies in chemical reactions	APK: Focus 3, pp. 100-102	
Friday, October 22	Change of Gibbs free energy with temperature and pressure	APK: Focus 3, pp. 106-110	
Monday, October 25	Phase transitions <ul style="list-style-type: none"> • Phase diagrams • Clausius-Clapeyron equation 	APK: Focus 4, pp. 120-123 & 128-134	
Wednesday, October 27	The thermodynamic description of mixtures <ul style="list-style-type: none"> • Partial molar quantities • Chemical potential • Chemical potential of an ideal gas and mixture of ideal gases 	APK: Focus 5, pp. 141-149	Solutions of Assignment 4 are released.
Friday, October 29	Chemical potential of liquids	APK: Focus 5, pp. 150-151	<p>QUIZ 4 Covers the same material as Assignment 4, i.e. Oct. 18-Oct. 27, inclusive</p> <p>Assignment 5 released. It covers Oct. 29-Nov. 17, inclusive</p>

November 1-7	Reading week		
Monday, November 8			MIDTERM #2 IN-CLASS Duration: 45 min, starts at 10:35 am, ends at 11:20 am Examinable material is from Oct. 6 to Oct 27, inclusive
	UNIT 5: COLLIGATIVE PROPERTIES		
Wednesday, November 10	Colligative properties <ul style="list-style-type: none"> • Raoult's law • Lowering of the freezing point and elevation of the boiling point 	APK: Focus 5, pp. 151 & 158-162	
Friday, November 12	Colligative properties <ul style="list-style-type: none"> • Osmotic pressure 	APK: Focus 5, pp. 162-165	
	UNIT 6: ACTIVITY AND ELECTROLYTES		
Monday, November 15	<ul style="list-style-type: none"> • Henry's law • Activity and Activity coefficients 	APK: Focus 5, pp. 183-186	
Wednesday, November 17	Electrolytes <ul style="list-style-type: none"> • The activities of ions 	APK: Focus 5, pp. 187-189	Solutions of Assignment 5 are released.
Friday, November 19	Electrolytes <ul style="list-style-type: none"> • The activities of ions (cont') 	APK: Focus 5, pp. 187-189	QUIZ 5 - Covers the same material as Assignment 5, i.e. Oct. 29- Nov. 17, inclusive
	UNIT 7: CHEMICAL EQUILIBRIUM		
Monday, November 22	Chemical Equilibrium <ul style="list-style-type: none"> • Relation of Equilibrium constant and change in 	APK: Focus 6, pp. 203-207	Assignment 6 is released. It covers material from Nov 19-

	free energy of the reaction		Dec. 1, inclusive.
Wednesday, November 24	Chemical Equilibrium <ul style="list-style-type: none"> Expressing the equilibrium constant in terms of activities Le Chatelier's principle van't Hoff equation 	APK: Focus 6, pp. 208-216	
Friday, November 26	Solving equilibrium constant related problems		
UNIT 8: ELECTROCHEMISTRY			
Monday, November 29	Electrochemistry <ul style="list-style-type: none"> Structure of an electrochemical cell The cell potential Nernst equation 	APK: Focus 6, pp. 217-223	Solutions to Assignment 6 are released.
Wednesday, December 1	Electrochemistry <ul style="list-style-type: none"> Electochemical series Determination of equilibrium constants 	APK: Focus 6, pp. 224-228	
Friday, December 3	Review		
Monday, December 6	Review		
Wednesday, December 8	Review		
Date to be determined by the registrar			FINAL EXAM Duration: 3 hours; cumulative on all the course material

Contingency plan for an in-person class pivoting to 100% online learning

In the event of a COVID-19 resurgence during the course that necessitates the course delivery moving away from face-to-face interaction, all remaining course content will be delivered entirely online, either synchronously (i.e., at the times indicated in the timetable) or asynchronously (e.g., posted on OWL for students to view at their convenience). The grading scheme will **not** change. Any remaining assessments will also be conducted online as determined by the course instructor.

Accommodation and Accessibility

Accessible Education

- Students with disabilities work with Accessible Education (formerly SSD) which provides recommendations for accommodation based on medical documentation or psychological and cognitive testing. The Academic Accommodation for Students with Disabilities policy can be found at:
https://www.uwo.ca/univsec/pdf/academic_policies/appeals/Academic_Accommodation_disabilities.pdf
- Please contact the course instructor if you require lecture or printed material in an alternate format or if any other arrangements can make this course more accessible to you. You may also wish to contact Student Accessibility Services (SAS) at (519) 661-2147 if you have any questions regarding accommodations.

Accommodation for Medical Illness or other Serious Circumstances

Students who experience an extenuating circumstance (illness, injury or other extenuating circumstance) sufficiently significant to temporarily render them unable to meet academic requirements may submit a request for academic consideration through the following routes:

- (i) Submitting a Self-Reported Absence (SRA) form provided that the conditions for submission are met. To be eligible for a Self-Reported Absence:
 - an absence must be no more than 48 hours
 - the assessments must be worth no more than 30% of the student's final grade
 - no more than two SRAs may be submitted during the Fall/Winter term
- (ii) For medical absences, submitting a Student Medical Certificate (SMC) signed by a licensed medical or mental health practitioner to the Academic Counselling office of their Faculty of Registration.
- (iii) Submitting appropriate documentation for non-medical absences to the Academic Counselling office in their Faculty of Registration.

Note that in all cases, students are required to contact their instructors within 24 hours of the end of the period covered, unless otherwise instructed in the course outline.

For further information, please consult the university's policy on academic consideration for student absences:

https://www.uwo.ca/univsec/pdf/academic_policies/appeals/Academic_Consideration_for_absences.pdf.

Students should also note that individual instructors are not permitted to receive documentation directly from a student, whether in support of an application for consideration on medical grounds, or for other reasons. **All documentation required for absences that are not covered by**

the Self-Reported Absence Policy must be submitted to the Academic Counselling office of a student's Home Faculty.

Religious Accommodation

Students should consult the University's list of recognized religious holidays, and should give reasonable notice in writing, prior to the holiday, to the Instructor and an Academic Counsellor if their course requirements will be affected by a religious observance. Additional information is given in the Western Multicultural Calendar:

<https://multiculturalcalendar.com/ecal/index.php?s=c-univwo>

Make-up exams: If a student misses a midterm exam, a make-up exam may be provided upon a recommendation from academic counseling. If the make-up date is still not met because of a valid reason, then the weighting of the miss exam, will be redistributed to other evaluation components. For example, if you miss Midterm 1, the weight of Midterm 2 will be doubled.

If you miss the final exam for a valid reason, a "Recommendation of Special Examination" form must be obtained from the Dean's Office. A special exam will be provided in the first weeks of January (date TBA).

Academic Policies

The website for Registrarial Services is <http://www.registrar.uwo.ca>.

E-mailing: In accordance with policy, <http://www.uwo.ca/its/identity/activatenonstudent.html>, the centrally administered e-mail account provided to students will be considered the individual's official university e-mail address. It is the responsibility of the account holder to ensure that e-mail sent by the University to his/her/their official university address is attended to in a timely manner.

Electronic devices: electronic devices will or will not be permitted on tests and exams. Only a non-programmable calculator can be used in midterms and final exam.

Scholastic offences: Scholastic offences, including plagiarism, are taken seriously and students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence, at the following Web site: http://www.uwo.ca/univsec/pdf/academic_policies/appeals/scholastic_discipline_undergrad.pdf.

All required papers may be subject to submission for textual similarity review to the commercial plagiarism detection software under license to the University for the detection of plagiarism. All papers submitted for such checking will be included as source documents in the reference database for the purpose of detecting plagiarism of papers subsequently submitted to the system. Use of the service is subject to the licensing agreement, currently between The University of Western Ontario and Turnitin.com (<http://www.turnitin.com>).

Code of Conduct: Students are reminded of the University's Code of Conduct found on the university website. To maintain a high standard of learning environment in our classrooms, those who are disruptive, rude, or show unacceptable behavior, either to the instructor, or the other students, will be asked to leave.

Support Services

Academic matters: Please visit the Science & Basic Medical Sciences Academic Counselling webpage for information on add/drop courses, academic considerations for absences, appeals, exam conflicts, and many other academic related matters: <https://www.uwo.ca/sci/counselling/>

Managing academics and well-being: Western University is committed to a thriving campus as we deliver our courses in the mixed model of both virtual and face-to-face formats. We encourage you to check out the Digital Student Experience website to manage your academics and well-being: <https://www.uwo.ca/se/digital/>.

Learning-skills Services: Learning-skills counsellors at the Student Development Centre (<http://www.sdc.uwo.ca>) are ready to help you improve your learning skills. They offer presentations on strategies for improving time management, multiple-choice exam preparation/writing, textbook reading, and more. Individual support is offered throughout the Fall/Winter terms in the drop-in Learning Help Centre, and year-round through individual counselling.

Emotional/mental distress services: Students who are in emotional/mental distress should refer to Mental Health @ Western (<https://www.uwo.ca/health/psych/index.html>) for a complete list of options about how to obtain help.

Other services: Additional student-run support services are offered by the USC, <https://westernusc.ca/your-services/#studentservices>

Tips for studying for the course

Before the class

- **Prepare.** The lecture notes will be provided in advance. The relevant material of the textbook for all the course is found in this course outline. It is helpful to do a reading of the upcoming lecture notes and/or textbook material before the class.
- **Review.** Review the material of first year chemistry related to ideal gas law, thermodynamics, thermochemistry, equilibrium constant, concentration and how to express concentration using different units and how to convert the units of concentration, electrochemistry. Review the units of the physical quantities and how to convert units.
- Do the checklist points shown in each lesson on owl.

Inside the class

- **Attend the classes.**
- **Note the tricky points.**

- **Stay focused.** Avoid any distractions such as use of cell phones and laptops. Please keep all these devices turned off and even better do not bring them in the class. **Cell phones and laptops should be turned-off during the class. Laptops can be used during the allotted quiz time in order to complete the quiz.**
- **Solve the problems in the class.** Every time we do a problem, a few minutes will be given to the students to do the problem themselves before I discuss the solution in the class.
- **Participate** in the class by trying to answer the questions. An incorrect answer can be very useful for building a discussion of the topic around it.
- **Ask questions.**

Progress and Self-assessment

- The expectation is the for every hour of lectures, a student spends two-three hours on self-study.
- Do the assignments. You can collaborate with other students in the assignment preparation.
- Do the assignments gradually throughout the lectures they cover so as you learn the material in a good pace.
- Study for the quizzes and participate in the quizzes. **Do the quizzes yourself** so as you assess yourself that you meet the learning goals.
- Do the solved problems of the textbook by yourself first and then study the solution. Justify every step you do to solve the problem. **Always ask yourself: why am I doing this step in the solution of the problem?**
- Do the suggested problems (list of suggested problems for all the topics of the course is provided at the beginning of the course).
- The lecture notes provide the key ideas, but the textbook discusses more details. Your reading should include both, lecture notes and textbook reading.
- For the students who are interested in learning more on thermodynamics and its applications, current scientific literature will be posted in owl for optional reading.
- Use the forum on owl and the office hours. Try to respond to the questions of your peers in the forum.

Important Academic Dates (Sept 2021 – December 2021)

- September 8 – Classes begin
- September 16 - Last day to add a full course or first-term half course
- October 11 – Thanksgiving Holiday
- November 1-7 – Fall Study week (Monday – Sunday)
- November 12 - Last day to withdraw from a first-term half course without academic penalty
- December 8 – Fall classes end
- December 9 – Study day
- December 10-21 December examination period
- January 3, 2022 – Classes resume