WESTERN UNIVERSITY
DEPARTMENT OF CHEMISTRY

CHEM 2374A – Thermodynamics

COURSE OUTLINE 2022

Welcome to CHEM 2374A!

Instructor Information

Instructor Dr. Styliani Constas, ChB 071 (Lower ground floor in the Chemistry Building)
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Teaching Assistant Kwang Odonnell

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Course Information

Prerequisites and anti-requisites
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.

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.

Schedule and Delivery Mode

Lecture hours and Location Monday, Wednesday, Friday 10:30-11:20 am, MC-105B

Delivery Mode: In-person

Office hours: Every Monday and Wednesday 4:00 pm-5:00 pm preferably on zoom.

Zoom connection details will be posted on owl.

Meetings with the TA for asking questions on the material can be arranged by appointment.

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, affected 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.

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

Course Syllabus

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.

Textbooks & Readings

- 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.**

  The bookstore has also an ebook version that the students can purchase through the Book Store's website:
  https://bookstore.uwo.ca/textbooks-and-course-materials
- 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 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.

Assessments worth 10% or more of the overall course grade:

For missed work worth 10% or more of the final course grade, you must provide valid medical or supporting
documentation to the Academic Counselling Office of your Faculty of Registration as soon as possible.
For further information, please consult the University's medical illness policy at https://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_medical.pdf.
The Student Medical Certificate is available at
https://www.uwo.ca/univsec/pdf/academic_policies/appeals/medicalform.pdf

Accommodation for Medical Illness or other Serious Circumstances

If you are unable to meet midterms, or final course requirement due to illness or other serious circumstance, you must provide valid medical documentation or other supporting documentation to the Dean's office as soon as possible and contact the course coordinator instructor immediately. For missed quizzes, please read the details in the Course Evaluation for Quizzes. In some cases missed quizzes may require medical documentation to be provided to the Dean's office. **It is your responsibility to make** alternative arrangements with the instructor once the accommodation has been approved by the Dean's office and the instructor has been informed.

Students requiring academic accommodation due to illness for any assignment/exam should use the Student Medical Certificate when visiting an off-campus medical facility or request a Record's Release Form (located in the Dean's Office) if you visit Student Health Services.

The Student Medical Certification form can be downloaded from this link: http://www.uwo.ca/univsec/pdf/academic_policies/appeals/medicalform_15JUN.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 must be submitted to the Academic Counselling office of a student's Home Faculty.**

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.
- **6 Quizzes out of which the best 5 Quizzes will be counted toward the course grade**: 5X**1 % each = 5%** of the course grade.

  Students who write all 6 quizzes (<u>and only those students</u>) will receive a bonus: only the best 5 quiz marks will be counted toward the course grade.

  What is the content of the quiz?
    - Each quiz corresponds to the material of one assignment.
    - The quizzes will be on-line so you can do it any time of the day. The quiz will be open for 2 days apart for Quiz 1, that will be open for 1 day.
    - 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 the next day. **The quizzes will be open for two days, apart from quiz 1 that will be open for one day.** 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). It is strongly recommended to do the quiz during the work hours so you can be helped by owl support if you have any technical issues. The instructor and TA cannot help with technical problems.

Missed quiz?

- There are 6 quizzes in the course. No documentation is required if only one quiz is missed. Students who write all 6 quizzes (and only those students) will receive a bonus: only the best 5 quiz marks will be counted toward the course grade. Students who write fewer than 5 quizzes and wish to be excused must provide medical documentation to the Faculty of Science Dean's Office which will make the determination whether accommodation is warranted. The weight of each excused quiz will be redistributed among the other quizzes.

- **Mid-terms: 20% each X 2 = 40%** of the course grade.
  - The duration of each midterm is 45 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 at least one midterm exam 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.

Discussion for make-up exams is found in the ``Accommodation and Accessibility'' Section.

Tentative Lecture Schedule

Notes

1. **In the schedule that follows, <u>the due dates, the dates of the quizzes, midterms and posting of the assignments are firm</u>.** The schedule of lecture material is **tentative**. 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 **A**tkins, Julio de **P**aula, and James **K**eeler, **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
Friday, September 9	Welcome back! Course Introduction and strategies to study for the course	Course syllabus	
	UNIT 1 - FUNDAMENTALS AND EQUATIONS OF STATE		
Monday, September 12	• 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	
Wednesday, September 14	• Meaning of pressure • Equation of State	APK: Focus 1, pp. 6-10	Assignment 1 is released

	• Perfect (ideal) gas law • Mixture of gases		to the students – it covers material from Sept. 12-Sept. 21 inclusive **Assignments are not graded**
Friday, September 16	• Deviation of the prefect gas from real gases • Compression factor • Relation to intermolecular interactions • Van der Waals equation of state	APK: Focus 1, pp. 19-22	
Monday, September 19	• Explanation of the van der Waals isotherms • Law of corresponding states • Significance of the van der Waals equation	APK: Focus 1, pp. 19-27	
Wednesday, September 21	• 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		
Friday, September 23	• work, different types of work, volume-change work, surface tension work • heat • internal energy	APK: Focus 2, pp. 33-38	**QUIZ 1 – Covers the same material as Assignment 1, i.e. Sept.**

	• molecular interpretation of internal energy		**12-Sept. 21, inclusive** **The quiz is open Sept. 23 00:01 am – 11:59 pm (one day)**
Monday, September 26	• 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. 23-Oct. 3, inclusive
Wednesday, September 28	• Estimating work, heat internal energy for Isothermal and Isobaric processes • Maximum work	APK: Focus 2, pp. 38-42	
Friday, September 30	• Heat Capacity • Enthalpy	APK: Focus 2, pp. 42-45; 46-50	
Monday, October 3	• Thermochemistry	APK: Focus 2, pp. 51-58	Solutions to Assignment 2 are released
Wednesday, October 5	• State function and exact differentials • Partial derivatives • Examples	APK: Focus 2, pp. 59-63	**QUIZ 2 Covers the same material as Assignment 2, i.e. Sept. 23-Oct. 3rd, inclusive**

	UNIT 3: ENTROPY AND THE 2nd LAW; 3rd LAW		
Friday, October 7	• 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. 5-Oct. 14, inclusive
Monday October 10	**Thanksgiving**		
Wednesday, October 12			**MIDTERM #1 IN-CLASS Duration: 45 min; starts at 10:35 am, ends at 11:20 am. Examinable material is from Sept. 12 to Oct 5th, inclusive**
Friday, October 14	• Estimation of entropy changes	APK: Focus 3, pp. 88-91	
Monday, October 17	• 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		
Wednesday, October 19	Helmholtz and Gibbs free energy	APK: Focus 3, pp. 97-100	**QUIZ 3 - Covers the same material as Assignment 3, i.e. Oct. 5-Oct. 14, inclusive** Assignment 4 released. It covers Oct. 19-Oct. 26, inclusive.
Friday, October 21	Changes in the Gibbs free energies in chemical reactions	APK: Focus 3, pp. 100-102	
Monday, October 24	Change of Gibbs free energy with temperature and pressure	APK: Focus 3, pp. 106-110	
Wednesday, October 26	Phase transitions • Phase diagrams • Clausius-Clapeyron equation	APK: Focus 4, pp. 120-123 & 128-134	
Friday, October 28	The thermodynamic description of mixtures • 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.

October 31-Nov. 6	Reading week		
Monday, November 7	Chemical potential of liquids	APK: Focus 5, pp. 150-151	**QUIZ 4 Covers the same material as Assignment 4, i.e. Oct. 19-Oct. 26, inclusive**
Wednesday, November 9			**MIDTERM #2 IN-CLASS Duration: 45 min, starts at 10:35 am, ends at 11:20 am Examinable material is from Oct. 7 to Nov 7, inclusive**
	UNIT 5: COLLIGATIVE PROPERTIES		
Friday, November 11	Colligative properties • Raoult's law • Lowering of the freezing point and elevation of the boiling point	APK: Focus 5, pp. 151 & 158-162	Assignment 5 released. It covers Oct. 28-Nov. 18, inclusive
Monday, November 14	Colligative properties • Osmotic pressure	APK: Focus 5, pp. 162-165	

	UNIT 6: ACTIVITY AND ELECTROLYTES		
Wednesday, November 16	• Henry's law • Activity and Activity coefficients	APK: Focus 5, pp. 183-186	
Friday, November 18	Electrolytes • The activities of ions	APK: Focus 5, pp. 187-189	Solutions of Assignment 5 are released.
	UNIT 7: CHEMICAL EQUILIBRIUM		
Monday, November 21	Chemical Equilibrium • Relation of Equilibrium constant and change in free energy of the reaction	APK: Focus 6, pp. 203-207	**QUIZ 5 - Covers the same material as Assignment 5, i.e. Oct. 28-Nov. 18, inclusive** Assignment 6 is released. It covers material from Nov 21-Nov. 30, inclusive.
Wednesday, November 23	Chemical Equilibrium • Expressing the equilibrium constant in terms of activities	APK: Focus 6, pp. 208-216	

	• Le Chatelier's principle • van't Hoff equation		
Friday, November 25	Solving equilibrium constant related problems		
	UNIT 8: ELECTROCHEMISTRY		
Monday, November 28	Electrochemistry • Structure of an electrochemical cell • The cell potential • Nernst equation	APK: Focus 6, pp. 217-223	Solutions to Assignment 6 are released.
Wednesday, November 30	Electrochemistry • Electochemical series • Determination of equilibrium constants	APK: Focus 6, pp. 224-228	
Friday, December 2	Finish-up any material left from the previous schedule		**QUIZ 6 - Covers the same material as Assignment 6, i.e. Nov. 21-Nov. 30, inclusive**
Monday, December 5	Review		
Wednesday, December 7	Review		
Date to be determined by the registrar			**FINAL EXAM Duration: 3 hours; cumulative on all the course material**

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.

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 missed 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 Midterm 2, the weight will be transferred to Midterm 1.

If you miss both makeup exams, one makeup midterm test will be offered on November 14 only to those students who receive academic consideration for BOTH midterms. Time and place of the exam to be determined. The students who are to write this make-up exam should inform the instructor as soon as possible after the regular Midterm 2 exam. **This makeup test will have the same length as a regular midterm but will be cumulative in coverage.** For the purposes of evaluation, the makeup test will be treated as one regular midterm. The rest of the weight will be transferred to the final exam.

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 destructions 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.**
- **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 2022 – December 2022)

- September 8 – Classes begin
- September 16 - Last day to add a full course or first-term half course
- October 8-10 – Thanksgiving Weekend
- October 31 – November 6 - Fall Study week (Monday – Sunday)
- November 9 - Date by which students in a first-term half course must receive assessment for work totaling 15% of their final grade (1000- and 2000-level courses only)
- November 12 **-** Last day to withdraw from a first-term half course without academic penalty (extended to Nov. 14 as Nov. 12 falls on a weekend)
- December 8 – Fall classes end
- December 9 – Study day
- December 10-22 December examination period
- January 9, 2023 – Classes resume