Chemistry
UNIVERSITY OF TORONTO

CHM 217H: Introduction to Analytical Chemistry

Fall 2021 Course Syllabus

I INSTRUCTOR

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II COURSE OVERVIEW

COURSE DESCRIPTION:

CHM 217H1 is the first in a series of courses designed to introduce students to the topic of chemical detection and measurement. As well as being a varied and interesting discipline in its own right, analytical chemistry plays an essential role in many other important subjects such as biochemistry, clinical chemistry, environmental science, food and nutrition, forensic science, organic chemistry and spectroscopy, medicinal and pharmaceutical chemistry, pharmacology, and toxicology. Whether performing blood tests, verifying the safety of our food and drinking water, determining the cause of a fire, or identifying genetic disease markers, analytical chemistry touches every aspect of our daily lives.

This course introduces the fundamental principles of chemical measurement used in medical diagnosis, quality assurance and control, and research studies. It will teach you how to correctly handle and interpret experimental measurements, compare results and procedures, and calibrate analytical instrumentation. You will also learn how to perform many analytical procedures including volumetric analysis, potentiometry, UV/visible and infrared spectrophotometry, flame atomic spectrometry, and chromatography.

STUDENT LEARNING OUTCOMES:

By the end of the course, students will be expected to demonstrate the following core competencies:

- To identify different types and sources of error, perform relevant statistical analyses of experimental data, and draw appropriate conclusions from the results.
- To analyse, interpret, and communicate data and findings in a scientifically valid and effective manner.
- To be familiar with and implement standard operating procedures to accurately and precisely prepare standard solutions, calibrate

instrumentation, and competently perform common methods of quantitative chemical analysis.
- To work both individually and collaboratively as part of a small team or group in order to accomplish an experimental goal, such as characterize a method of analysis or complete a specific chemical determination.
- To access, understand, and apply information from Material Safety Data Sheets in order to safely conduct chemical experiments and appropriately deal with any generated waste products.
- To develop the practice of accurate and timely data recording, in accordance with the principles of Good Laboratory Practice (GLP).
- To apply knowledge of the operating principles of specific analytical methods and instrumentation to the identification and remediation of potential interferences from sample composition in chemical analyses.

PREREQUISITE COURSE(S):

This course assumes you have a basic understanding of material covered in high school chemistry and the prerequisite courses CHM151Y or CHM135H+CHM136H (or equivalent). This includes the following topics:

- Significant figures, decimal places, and rounding in calculations
- Fundamental SI units and common unit prefixes; unit conversion
- Common chemical units and their conversion to/from SI units
- Interpretation of simple chemical names and formulae
- Calculation of molecular and formula masses
- Concentration calculations (molar, molal, mass, mole fraction, density)
- Balancing equations; stoichiometry & limiting reagent calculations
- Identification and balancing of acid-base, precipitation and redox reactions
- Formal oxidation numbers; identification of oxidant and reductant
- Definition of the equilibrium constant; relations between K, Q, and ΔG
- Basic principles of equilibrium calculations; combination of equilibria
- Acids and bases (Arrhenius, Brønsted-Lowry, and Lewis); acid & base strength
- Calculation of pH, K_a, K_b, and equivalence point in acid-base titrations
- Identification of buffers, calculation of buffer composition & pH
- Solubility, precipitation, K_{sp}, and solubility calculations
- Standard reduction potentials, electrodes and cells; the Nernst equation
- Chemical bonds (covalent, ionic, coordinate); atomic & molecular orbitals
- Naming, identity, structure, and properties of common functional groups (alkane, alkene, alkyne, alkyl halide, alcohol, aldehyde, ketone, carboxylic acid, ester, ether, phenyl, *etc*.)
- Molecular orbital description of σ and π bonds
- Definition & origin of bonding, non-bonding & anti-bonding MOs
- Delocalization and aromaticity (phenyl group, conjugated alkenes and enones)

This course is a prerequisite for the following course(s): CHM 317H1, CHM 410H1, CHM 414H1, and CHM 416H1.

READINGS:

Course handouts indicate the sections/pages in either of the required course texts related to the material under discussion. Suggested problems and text sections for the following material will be included at the end of each handout. Students may use either of the following as the required textbook:

- Skoog *et al*, "Fundamentals of Analytical Chemistry", 9th edition, Brooks-Cole/Cengage Learning
- Harvey, "Analytical Chemistry 2.1", LibreTexts™, https://chem.libretexts.org/Bookshelves/Analytical_Chemistry/Book%3A_Analytical_Chemistry_2.1_(Harvey)

Supplemental:

The course will use some supplemental on-line materials, some of which you are expected to watch and take notes on. Other materials will be provided as quick 'refresher' modules that can be viewed at your discretion. You will also be provided with links to additional on-line resources that will assist you in completing tutorial exercises and lab activities.

III COURSE ORGANIZATION

This course is organized by units, each of which takes approximately 1-2 weeks. Lectures, labs, and tutorials will all be held in-person unless changes are required as a result of public health directives from the city or province. Lecture recordings will be provided via Quercus within 1-2 days.

The mandatory laboratory will occupy nine weeks over a ten-week period within the semester. Students will be assigned to demo groups within each lab section, within which they will work individually, in pairs, and in small teams, depending on the assigned experiment. Experiments are performed in blocks on rotation, so each demo group will be performing a different experiment each week.

There will be five tutorials over the course of the semester, held on alternate weeks to the Friday lecture. Some of these will focus on activities related to the lecture and lab material and have assignments associated with them. The others will serve as review sessions for the two term tests.

COURSE SCHEDULE & RELEVANT SESSIONAL DATES:

Note that all dates are provisional; some units may start or end on different dates than shown here.

DATES	UNIT	TOPICS
Sept. 9	0	Introduction to Analytical Chemistry. Please note that students are a required to view and take notes on a short video prior to this lecture.
Sept. 10 – Sept. 24	1	Statistics in analytical chemistry: measurement terminology; errors in measurement; error estimates; the Gaussian

		(Normal) distribution; significance tests; calibration; regression analysis
Sept. 28 – Oct. 8	2	Analysis using stoichiometric reactions: standards and reference materials; volumetric analysis – titrations, complexometry, and gravimetry
Oct. 12 – Oct. 22	3	Electrochemical methods of analysis: redox titrations, Nernst equation, potentiometry, reference electrodes, membrane electrodes (pH and ISEs); potentiometric titrations
Oct. 28 – Nov. 5	4	Molecular spectrophotometric methods: electromagnetic radiation; electronic transitions; Beer's Law; UV/visible instrumentation & applications; molecular rovibrational transitions; basic IR and FTIR instrumentation & applications (qualitative & quantitative)
Nov. 16 – Nov. 25	5	Atomic absorption and emission methods: atomic line spectra; Maxwell-Boltzmann equation; atom sources, sample introduction, & flame processes; FAAS & FAES; interference effects, calibration & standards addition
Nov. 30 – Dec. 7	6	Brief introduction to chromatography: separation mechanisms; definitions (retention, resolution, etc.); gas and liquid chromatography instruments & applications; optimization, resolution, method selection

TUTORIAL OBJECTIVES:

Five tutorials are scheduled every other week, commencing in the third week of classes. These are intended to supplement the lecture material by providing opportunities to engage with typical analytical problems and calculations, and will focus on problem-solving strategies. In-class activities and follow-up assignments will be drawn from both assigned problems and prior years' term tests and final exams. Two of the tutorials will provide practice problems in advance of the two term tests.

LABORATORY OBJECTIVES:

Analytical chemistry is a highly practical subject. The **mandatory** laboratory sessions reflect the topics addressed in lectures and provide an opportunity to see and use a variety of common analytical procedures and instruments. This will allow students to develop the technical skills necessary to perform a variety of common chemical methods of analysis. Labs also provide ample opportunities for students to develop their collaboration and communication skills through frequent group work.

IV EVALUATION/GRADING SCHEME

OVERVIEW:

Assignments (best 2 out of 3): 10%
Laboratory (see lab manual for grades breakdown): 35%
Term Tests (x2, best mark counts for 15%): 25%
Final Exam (cumulative): 30%

NOTE: The final exam will be in-person during the scheduled December examinations period (December 10th-21st). Term tests may be in-person, on-line, or a hybrid; options will be discussed in class during the first week before a final decision is made.

ASSESSMENT DATES & MARK BREAKDOWN:

For students missing one term test for a valid reason, the missed test grade will be calculated based on performance on the other two term tests and the class average of the other two tests. **For students missing both tests for valid reasons the mark for the missing tests will be replaced by a cumulative, two-hour assessment to be written during the April final assessment period. This assessment will cover all aspects of both the laboratory and classroom components of the course.**

V COURSE POLICIES

- Each member of this course is expected to maintain a:
  - (i) professional and respectful attitude during all course activities, including classes, laboratories, tutorials, and online activity.
  - (ii) personal calendar/schedule/organizer to ensure that all course activities are completed, and due dates are met.
  - (iii) collection of notes recorded independently based on concepts covered in course activities (students registered with Accessibility Services requiring a class note-taker will have access to this accommodation)
  - (iv) familiarity with the university policy on Academic Integrity (overleaf)
- The University of Toronto is committed to equity, human rights, and respect for diversity. All members of the learning environment in this course should strive to create an atmosphere of mutual respect where all members of our community can express themselves, engage with each other, and respect one another's differences. As a Course Instructor, I will neither condone nor tolerate behaviour that undermines the dignity or self-esteem of any individual in this course and wish to be alerted to any attempt to create an intimidating or hostile environment. It is our collective responsibility to create a space that is inclusive and welcomes discussion. Discrimination, harassment and hate speech will not be tolerated. If you have any questions,

comments, or concerns, we encourage you to reach out to the staff in our Equity Offices.

- Communication with the instructor: students should email from their U of T email account. Please allow at least one business day for a response.
- All interactions are expected to conform with the University statement regarding a positive learning environment: "*The University of Toronto is committed to equity, human rights and respect for diversity. All members of the learning environment in this course should strive to create an atmosphere of mutual respect where all members of our community can express themselves, engage with each other, and respect one another's differences. U of T does not condone discrimination or harassment against any persons or communities*."
- Privacy and appropriate use of course materials: See section VII, Copyright.
- Policy for late assignment submissions: a penalty of 5% of the maximum mark per will be deducted daily for term work submitted past the deadline. Exceptions:
    - An extension had been agreed to by the instructor prior to the deadline
    - An emergency arose and any notification/documentation was completed in accordance with the Rules and Regulations as posted in the Faculty of Arts & Science Calendar
- Missed academic work: Students will either be given an opportunity to make up the missed work (such as performing a lab experiment) or offered a reweighting scheme commensurate with the nature of the missed work and closeness to the end of term. This may include shifting the marks to a different item of work, or assigning a grade based on comparable term work relative to the class average.
- Submission methods: students are responsible for checking the time, date, and submission process for each item of term work. Generally, submissions will be made through Quercus.
- Process for requesting re-grading of course work: Students are responsible for submitting requests for re-grading before deadlines established by the Faculty of Arts & Science (see https://artsci.calendar.utoronto.ca/petitions-and-appeals). Generally, requests should be made by email within one week of receiving the graded term work.
- Process for signalling course absences and requesting make-up tests or exams: Students are responsible for notifying the course instructor of any known absences or timetable conflicts in a timely manner. In the event of illness, students should notify the course instructor as soon as practically possible, especially if the absence coincides with a scheduled lab class.

In the laboratory:

- Every student is expected to always observe proper safety procedures. This includes the wearing of personal protective equipment, following correct procedures when handling and disposing of chemicals, dealing with and

reporting any spills or accidents promptly, and maintaining awareness of those around them.

- For collaborative experiments, every student is expected to contribute equally to the work, and to perform their share of both the experiment and clean-up. Further expectations around communication, data processing, and timely sharing of information are set out in the lab manual.

VI TECHNOLOGY REQUIREMENTS

- Specific guidance from the U of T Vice-Provost, Students regarding student technology requirements is available here: https://www.viceprovoststudents.utoronto.ca/covid-19/tech-requirements-online-learning/

- This course requires the use of computers, and technical issues are possible. When working on a piece of academic work, students are responsible for scheduling enough time to allow for reasonable delays due to technical difficulties to be overcome, so such issues will not be acceptable grounds for deadline extension. Particularly, maintaining an up-to-date independent backup copy of your work is strongly recommended to guard against hard-drive failures, corrupted files, lost computers, etc.

VII INSTITUTIONAL POLICIES & SUPPORT

ACADEMIC INTEGRITY

Academic integrity is essential to the pursuit of learning and scholarship in a university, and to ensuring that a degree from the University of Toronto is a strong signal of each student's individual academic achievement. As a result, the University treats cases of cheating and plagiarism very seriously. The University of Toronto's Code of Behaviour on Academic Matters (governingcouncil.utoronto.ca/secretariat/policies/code-behaviour-academic-matters-july-1-2019) outlines the behaviours that constitute academic dishonesty and the processes for addressing academic offences. Potential offences include, but are not limited to:

In laboratory reports:

1. Using someone else's ideas or words without appropriate acknowledgement.
2. Submitting your own work in more than one course without the permission of the instructor.
3. Making up sources or facts.

On quizzes and term tests:

1. Looking at someone else's answers or collaborating/discussing answers during a quiz or term test.
2. Misrepresenting your identity.

In all academic work:

1. Falsifying institutional documents or grades.
2. Falsifying or altering any documentation required by the University.
3. Obtaining or providing unauthorized assistance on any report. **Please note that the use of websites (such as Chegg.com or other discussion platforms) to post laboratory report material/questions or to post/access answers to questions is an academic offence under the University of Toronto's Code of Behaviour on Academic Matters. Alleged instances of this nature are forwarded to the Faculty of Arts & Science Student Academic Integrity office.**

All suspected cases of academic dishonesty will be investigated following procedures outlined in the Code of Behaviour on Academic Matters. If you have questions or concerns about what constitutes appropriate academic behaviour or appropriate research and citation methods, you are expected to seek out additional information on academic integrity from your instructor or from other institutional resources (see www.academicintegrity.utoronto.ca/).

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Lecture recordings and other materials are provided through Quercus solely for use by students within this course. They may not be posted, altered, published, or shared by any means. If a student wishes to copy or reproduce class presentations, course notes or other similar materials provided by instructors, he or she must obtain the instructor's written consent beforehand. Otherwise, all such reproduction is an infringement of copyright and is absolutely prohibited. More information regarding this is available here: https://teaching.utoronto.ca/ed-tech/audio-video/copyright-considerations/

ACCESSIBILITY NEEDS

Students with diverse learning styles and needs are welcome in this course. The University of Toronto is committed to accessibility: if you require accommodations for a disability, or have any other accessibility concerns about the course, please contact Accessibility Services as soon as possible.

ACCOMMODATIONS FOR RELIGIOUS OBSERVANCES

Following the University's policies, reasonable accommodations will be made for students who observe religious holy days that coincide with the due date/time of an assignment, tutorial, class or laboratory session. Students must inform the instructor **before** the session/assignment date to arrange accommodations.

ADDITIONAL SERVICES & SUPPORT

The following are some important links to help you with academic and/or technical service and support:

- General student services and resources at Student Life
- Full library service through University of Toronto Libraries

- Resources on conducting online research through University Libraries Research
- Resources on academic support from the Academic Success Centre
- Learner support at the Writing Centre
- Information for Technical Support/Quercus Support

ACKNOWLEDGEMENT OF TRADITIONAL LANDS

We wish to acknowledge this land on which the University of Toronto operates. For thousands of years, it has been the traditional land of the Huron-Wendat, the Seneca and, most recently, the Mississaugas of the Credit River. Today, this meeting place is still the home to many Indigenous people from across Turtle Island and we are grateful to have the opportunity to work on this land.