

**Course:** CHEM 3320, Instrumental Analysis (**undergraduate students**), 3.0 credits

**Location:** M/W/F 8:30 – 9:20 am, VOTEY BLDG 305

**Instructor:** Prof. David Punihaole

**Office:** INNOVATION HALL E352

**Email:** [David.Punihaole@uvm.edu](mailto:David.Punihaole@uvm.edu)

**Office Hours:** TBD

**Prerequisite:** Quantitative Analysis (CHEM 2310)

**Course Description:** This 3-credit course presents a survey of instrumental methods of chemical analysis. Students are expected to draw upon knowledge from previous courses they have taken, including General Chemistry, Quantitative Analysis, Introductory Physics, and Calculus. We will focus on understanding the fundamental principles underlying different methods and their realization in modern instrumentation for chemical analysis. We will broadly focus on the following areas:

- Signal and noise analysis
- Spectroscopy
- Mass spectrometry
- Chromatography

This is not a “how-to” course. You will not learn how to operate analytical instruments, nor will we cover specific analytical “recipes.” These change (sometimes quite quickly) with advances in the field and changes in technology, so our focus on principles and concepts of implementation should provide greater insight both into how current instruments work as well as the basis for your understanding how they will work a decade from now. Lastly, we will pay attention to the chemical systems to which these methods are applicable and how best to obtain the chemical information desired using the most appropriate instrumental methods.

**Course Learning Objectives:** This course fulfills core competencies in **analytical/critical thinking** and **quantitative reasoning/applied data interpretation**. You should develop an understanding of the analytical capabilities of several instrumental methods and be able to suggest suitable instrumental methods for specific problems and applications in chemistry. To choose the best instrumental method for addressing an analytical chemistry problem, we will consider:

- The property or quantity of the chemical system to be measured.
- The physical and chemical principles upon which the measurement is based.
- Generation of a signal by a suitable detector (transducer) and the processing of the signal to convert it to a form appropriate for a readout device.

- The strengths and limitations of different instrumental methods.

To make these kinds of assessments, you will need to assess:

- The chemical and/or physical principles exploited during the measurement.
- How the instrument makes the measurement.
- Some of the techniques used to improve analytical figures of merit (such as accuracy, precision, and sensitivity).

**Course Materials:** The required textbook for the course is:

- Principles of Instrumental Analysis - 7th Ed. by Douglas A. Skoog, F. James Holler, and Stanley Crouch (ISBN 9781305577213)

The book is available at [Amazon](#), the [UVM Book Store](#), or the publisher, [Cengage](#).

Copies of the chapters belonging to these textbooks can be made available upon reasonable request to me. These copies are for educational purposes only. Please do not distribute these copies.

**Web Content:** Lecture notes, problem sets, problem set answer keys, and exams may be made available through Brightspace. These materials are available for all current, UVM-affiliated, students, but they may not be shared off-campus without permission of the instructor.

**Attendance Policy:** Attendance will be periodically taken for this course. You are expected to attend all lectures to do well. If you miss a lecture for any reason, it is your responsibility to catch-up on missed material. In keeping with UVM policy, students are excused due to any religious, illness, personal, or family emergency reasons. Students who miss class due to legitimate reasons should notify me as soon as possible, as well as make arrangements with the dean's office.

**Grading:** Grades will follow the standard UVM scale:

- A+: >96 – 100%
- A: >92 – 96%
- A-: >89 – 92%
- B+: >87 – 89%
- B: >82 – 86%
- B-: >79 – 82%
- C+: >76 – 79%
- C: >72 – 76%
- C-: >69 – 72%
- D+: >66 – 69%
- D: >62 – 66%
- D-: 60 – 62%
- F: <60%

**Graded Components:**

- *Exams (50%):* Five exams are scheduled for this course. They will each be worth 10% of your final grade. They are not cumulative, although the questions from the exams will draw upon concepts discussed throughout the course.
- *Problem Sets (40%):* A total of 5 problem sets will be assigned throughout the semester. Each problem set is worth 8% of your total grade. Problem sets will be due at the start of class on the due date listed. Submissions that are late due to illegitimate reasons will not be accepted.
- *Class Attendance (10%):* Attendance will be periodically taken on random days in the class. Students who are not present when attendance is taken will be counted as absent.

**Grading curve policy:** A grading curve may be applied at the end of the semester using my discretion.

**Grade Appeals:** Students who wish to dispute a grade or believe that a mistake was made grading an assignment, project, or exam may ask for clarification. Students should first email me with their question/concern. If necessary, students may schedule an appointment to discuss their grade. If the student wants their graded assignment reevaluated, I will re-grade the entire assignment.

If you would like to contest a grade at the end of the semester, please follow the procedures outlined in this policy: <https://www.uvm.edu/policies/student/gradeappeals.pdf>.

**Statement on Diversity and Inclusion:** I strive to create a classroom environment that supports students from a diverse set of backgrounds. Our society is composed of individual from diverse ethnic, socioeconomic, and educational backgrounds. Half of our society are women. I strongly believe that our best path forward to a stronger and more equitable society is to promote inclusiveness. It is my expectation that every member of this class will also support diversity and inclusion. If you read this sentence, please email me for bonus points. As a community, we should strive to uphold the ideals of Our Common Ground: <https://www.uvm.edu/president/our-common-ground>. I welcome any suggestions as to how I can promote a diverse and inclusive classroom.

**General statement regarding potential changes during the semester:** <http://catalogue.uvm.edu>/ The University of Vermont reserves the right to make changes in the course offerings, mode of delivery, degree requirements, charges, regulations, and procedures contained herein as educational, financial, and health, safety, and welfare considerations require, or as necessary to be compliant with governmental, accreditation, or public health directives.

**Green and Gold Promise:** The Green and Gold Promise clearly articulates the expectations that UVM has for students, faculty, and staff to remain compliant with all COVID-19 recommendations from the federal CDC, the State of Vermont, and the City of Burlington. The Code of Student Conduct outlines policies related to violations of the Green and Gold Promise. Sanctions for violations include fines, educational sanctions, parent notification, probation, and suspension.

**Intellectual Property Statement/Prohibition on Sharing Academic Materials:** Students are prohibited from publicly sharing or selling academic materials that they did not author (for example: class syllabus, outlines or class presentations authored by the professor, practice

questions, text from the textbook or other copyrighted class materials, etc.); and students are prohibited from sharing assessments (for example homework or a take-home examination). Violations will be handled under UVM's Intellectual Property policy and Code of Academic Integrity.

**Student Learning Accommodations:** In keeping with university policy, any student with a documented disability interested in utilizing accommodations should contact SAS, the office of Disability Services on campus. SAS works with students and faculty in an interactive process to explore reasonable and appropriate accommodations, which are communicated to faculty in an accommodation letter. All students are strongly encouraged to meet with their faculty to discuss the accommodations they plan to use in each course. A student's accommodation letter lists those accommodations that will not be implemented until the student meets with their faculty to create a plan.

**Contact SAS:**

A170 Living/Learning Center  
802-656-7753  
access@uvm.edu  
[www.uvm.edu/access](http://www.uvm.edu/access)

**Religious Holidays:** Students have the right to practice the religion of their choice. If you need to miss class to observe a religious holiday, please submit the dates of your absence to me in writing by the end of the second full week of classes. You will be permitted to make up work within a mutually agreed-upon time. <https://www.uvm.edu/registrar/religious-holidays>.

**Academic Integrity:** The policy addresses plagiarism, fabrication, collusion, and cheating. <https://www.uvm.edu/policies/student/acadintegrity.pdf>.

**Code of Student Conduct:** <http://www.uvm.edu/policies/student/studentcode.pdf>

**FERPA Rights Disclosure:** The purpose of this policy is to communicate the rights of students regarding access to, and privacy of their student educational records as provided for in the Family Educational Rights and Privacy Act (FERPA) of 1974. <http://catalogue.uvm.edu/undergraduate/academicinfo/ferparightsdisclosure/>

**Promoting Health & Safety:** The University of Vermont's number one priority is to support a healthy and safe community:

**Center for Health and Wellbeing**

<https://www.uvm.edu/health>

**Counseling & Psychiatry Services (CAPS)**

Phone: (802) 656-3340

**C.A.R.E.**

If you are concerned about a UVM community member or are concerned about a specific event, we encourage you to contact the Dean of Students Office (802-656-3380). If you would like to remain anonymous, you can report your concerns online by visiting the Dean of Students website at <https://www.uvm.edu/studentaffairs>.

**Final Exam Policy:** The University final exam policy outlines expectations during final exams and explains timing and process of examination period. <https://www.uvm.edu/registrar/final-exams>.

**Statement on Alcohol and Cannabis in the Academic Environment:** As a faculty member, I want you to get the most you can out of this course. You play a crucial role in your education and in your readiness to learn and fully engage with the course material. It is important to note that alcohol and cannabis have no place in an academic environment. They can seriously impair your ability to learn and retain information not only in the moment you may be using, but up to 48 hours or more afterwards. In addition, alcohol and cannabis can:

- Cause issues with attention, memory and concentration.
- Negatively impact the quality of how information is processed and ultimately stored.
- Affect sleep patterns, which interferes with long-term memory formation.

**It is my expectation that you will do everything you can to optimize your learning and to fully participate in this course.**

## Course Schedule

### Week 1, 01/15 – 01/19 (Chapter 1)

- Lecture 1: Syllabus, introduction to instrumental analysis
- Lecture 2: Calibration of instrumental methods
- Lecture 3: Selecting analytical methods

### Week 2, 01/22 – 01/26 (Chapter 2)

- Lecture 4: Ohm's and Kirchoff's Laws, DC circuits
- Lecture 5: AC circuits, Capacitors
- Lecture 6: RC circuits

### Week 3, 01/29 – 02/02 (Chapters 3 & 5)

- Lecture 7: Signal and noise (**Problem set 1 due**)
- Lecture 8: Analog and digital filtering
- Lecture 9: Operational amplifiers, Lock-in amplification

### Week 4, 02/05 – 02/09 (Chapters 6 & 7)

- Lecture 10: Characteristics of electromagnetic radiation
- Lecture 11: General designs of optical instruments, sources of EM radiation
- **Exam 1 (Chapters 1 – 5)**

### Week 5, 02/12 – 02/16 (Chapter 7)

- Lecture 12: Wavelength selectors (**Problem set 2 due**)
- Lecture 13: Experimental considerations with spectrometers
- Lecture 14: Radiation Transducers

### Week 6, 02/19 – 02/23 (Chapter 13)

- **President's day (2/19), no class**
- Lecture 15: Beer's Law, UV-Vis absorption spectroscopy
- Lecture 16: Deviations from Beer's law

### Week 7, 02/26 – 03/01

- **No class**
- **No class**
- Lecture 17: UV-Vis experimental considerations

### Week 8, 03/04 – 03/08 (Chapters 14 & 16)

- Lecture 18: UV-Vis applications
- Lecture 19: Intro. to Infrared absorption spectroscopy
- **Exam 2 (Chapters 6 – 14)**

**Week 9, 03/11 – 03/15**

- **Spring break, no class**

**Week 10, 03/18 – 03/22 (Chapters 16 - 18)**

- Lecture 20: Fourier Transform IR instrumentation (**Problem Set 3 due**)
- Lecture 21: Sample handling, Attenuated total reflectance (ATR) IR
- Lecture 22: Intro. To Raman spectroscopy

**Week 11, 03/25 – 03/29 (Chapter 17 & 18)**

- Lecture 23: Raman experimental considerations, polarized measurements
- Lecture 24: Flavors of Raman spectroscopy (i.e., SERS, resonance Raman, SRS/CARS)
- Lecture 25: Applications of Raman and IR spectroscopy

**Week 12, 04/01 – 04/05 (Chapter 19)**

- Lecture 26: Intro. to NMR spectroscopy
- Lecture 27: Environmental effects on chemical shifts
- **Exam 3 (Chapters 16 – 18)**

**Week 13, 04/08 – 04/12 (Chapter 19)**

- Lecture 28: Spectral integration, spin-spin coupling (**Problem set 4 due**)
- Lecture 29: NMR instrumentation
- Lecture 30: NMR applications

**Week 14, 04/15 – 04/19 (Chapter 20)**

- Lecture 31: Intro. to molecular mass spectrometry, mass analyzers
- Lecture 32: Mass analyzers (cont'd), sampling methods (Guest Lecture: TBD)
- **Exam 4 (Chapter 19)**

**Week 15, 04/22 – 04/26 (Chapters 20 & 26)**

- Lecture 33: Mass spectrometry applications
- Lecture 34: Intro. to chromatography
- Lecture 35: Selectivity factor, band broadening, column efficiency

**Week 16, 04/29 – 05/03 (Chapter 27 & 28)**

- Lecture 36: Theory of band broadening (**Problem set 5 due**)
- Lecture 37: Gas chromatography and High-performance liquid chromatography
- Lecture 38: Chromatography applications

**Week 17, 05/06 – 05/10**

- **Exam 5 (Chapters 20, 26-28) on 05/06 at 07:30 am in Votey 305 (subject to change)**