CHEMISTRY

Overview & Learning Goals

Learning Goals

Mission Statement

Our mission is to help our students develop an understanding of and appreciation for chemistry, and to inspire and enable them to learn the practical and critical thinking skills necessary to both excel in their careers and to contribute to society as scientifically literate citizens. We believe that this mission is best accomplished using a two-pronged strategy:

1. by applying proven and innovative approaches to teaching and learning in the classroom and the laboratory; and
2. by coupling our classroom pedagogy to high-quality research at the frontiers of chemistry.

Mapping Learning Goals to the Chemistry Curriculum Chart (PDF) (https://www.bowdoin.edu/chemistry/pdf/chemistry-learning-goals-mapping.pdf)

Learning Outcomes for the Chemistry Major

Our students will understand, integrate, apply, and communicate fundamental and emerging chemical principles, moving from guided to self-designed investigations through courses or independent research. Our students will achieve these outcomes by meeting knowledge and skill-based competencies.

Chemistry Knowledge Competencies

1. Structure and properties
2. Synthesis, reactivity, and transformation
3. Energy, equilibrium, and kinetics
4. Models and measurements

Skill-Based Competencies

1. Apply problem-solving strategies to quantitative and conceptual problems
2. Perform routine laboratory activities safely and responsibly
3. Document laboratory activities and manage data responsibly and ethically
4. Use chemical instruments with an understanding of their principles, capabilities, and outputs
5. Interpret complex data sets and propose evidence-based conclusions
6. Apply theoretical, conceptual, and empirical models
7. Search, engage, and evaluate scientific literature and databases
8. Communicate chemistry effectively in written, visual, and oral formats
9. Work collaboratively
10. Independently propose, design, and implement experiments and approaches to address questions in chemistry

Options for Majoring or Minoring in the Department

Students may elect to major in chemistry, the chemistry and physics interdisciplinary major, or to coordinate a major in chemistry with digital and computational studies, education, or environmental studies. Students pursuing a coordinate or interdisciplinary major may not normally elect a second major. Non-majors may elect to minor in chemistry with the exception of students majoring in biochemistry.

Department Website (https://www.bowdoin.edu/chemistry/)

Faculty

Richard D. Broene, *Department Chair*
Sylvia Bosco, *Department Coordinator*

Professors: Richard D. Broene, Danielle H. Dube (Biochemistry), Elizabeth A. Stemmler‡, Dharni Vasudevan (Environmental Studies)
Associate Professor: Benjamin C. Gorske (Biochemistry), Kana Takematsu‡ (Biochemistry)
Assistant Professors: Michael Henderson, Amnon Ortoll-Bloch
Senior Lecturer: Michael P. Danahy
Visiting Faculty: Sean Lutz, Sanoj, Brandon Tate (Environmental Studies)
Laboratory Instructors: Rene L. Bernier, Martha B. Black, Kurt Luthy, Paulette M. Messier, Inoka Pathiraja, Abigail Snipe-Bushey, Denny Tesfa

Faculty/Staff Website (https://www.bowdoin.edu/chemistry/faculty-and-staff/)

Requirements

Chemistry Major

The chemistry major consists of a core curriculum and additional electives within a single area of concentration.

Code	Title	Credits
Required Courses		
Select one of the following: [a]		1
CHEM 1092	Introductory Chemistry and Quantitative Reasoning II	
CHEM 1102	Introductory Chemistry II	
CHEM 1109	General Chemistry	
CHEM 2100	Chemical Analysis	1
CHEM 2250	Organic Chemistry I	1
CHEM 2400	Inorganic Chemistry	1
Select one of the following: [b]		1
MATH 1700	Integral Calculus	
MATH 1750	Integral Calculus, Advanced Section	
placement above MATH 1750		
PHYS 1130 & PHYS 1140	Introductory Physics I and Introductory Physics II [c]	2
Select a concentration:		
Chemical Concentration (p. 2)		5
Educational Concentration (p. 2)		7
Environmental Concentration (p. 2)		5
Geochemical Concentration (p. 2)		5
Neurochemical Concentration (p. 2)		7

a Note that CHEM 1091 Introductory Chemistry and Quantitative Reasoning I are a prerequisite for CHEM 1092 Introductory Chemistry and Quantitative Reasoning II; CHEM 1101 Introductory Chemistry I is a prerequisite for CHEM 1102 Introductory Chemistry II. Placement above CHEM 1109 General Chemistry serves to meet this requirement and students do not have to replace the credit as part of the major requirements.

b Placement above MATH 1700 Integral Calculus/MATH 1750 Integral Calculus, Advanced Section satisfies the math requirement for the major and students do not have to replace the credit as part of the major requirements. Students intending to pursue graduate studies are encouraged to take a math course.

c Only one physics course is required for students placed into PHYS 1140 Introductory Physics II. Students placed above PHYS 1140 Introductory Physics II are not required to take a physics course to satisfy the requirements of the major, nor do they have to replace the credit in order to complete the requirements for the major. Note that PHYS 1130 Introductory Physics I is a prerequisite for PHYS 1140 Introductory Physics II.

Students are advised to begin their core curriculum as soon as possible. Depending on preparation and placement results, some students may begin with advanced courses.

Chemical Concentration

The Chemical Concentration consists of five credits.

Code	Title	Credits
CHEM 2260	Organic Chemistry II	1
or CHEM 2261	Organic Chemistry II with Research Laboratory	
CHEM 2510	Chemical Thermodynamics and Kinetics	1
CHEM 2520	Quantum Chemistry and Spectroscopy	1
Select two electives from the following: [d]		2
CHEM 2320	Biochemistry	
or CHEM 2550	Introduction to Computational Chemistry	
CHEM 3000 or higher		

d Only one course numbered 4000 or higher can serve as one of the two electives.

Educational Concentration

The Educational Concentration consists of seven credits.

Code	Title	Credits
CHEM 2510	Chemical Thermodynamics and Kinetics	1
or CHEM 2520	Quantum Chemistry and Spectroscopy	
EDUC 1101	Contemporary American Education [e]	1
EDUC 2203	Educating All Students [e]	1
EDUC 3301	Teaching and Learning [e]	1
EDUC 3302	Curriculum Development [e]	1
Select two additional chemistry electives in consultation with the advisor.		2

e These four courses also count toward an education minor or education coordinate major. This is the only exception to chemistry's double-counting rule for majors that allows only two courses to count double between two majors or a major and a minor.

Students interested in pursuing a minor or coordinate major in education, or the Bowdoin Teacher Scholars certification program, should consult with their major advisor as well as with a faculty member in the education department to discuss course selection and content area prerequisites.

Environmental Concentration

The Environmental Concentration consists of five credits.

Code	Title	Credits
CHEM 2510	Chemical Thermodynamics and Kinetics	1
Select two molecular perspective courses:		2
CHEM 2050	Environmental Chemistry	
CHEM 3050	Environmental Fate of Organic Chemicals	
CHEM 3055	Catalysis in Sustainable Chemical Processes	
CHEM 3060	Transformation of Organic Chemicals in the Environment	
CHEM 3100	Instrumental Analysis	
Select one environmental perspectives course:		1
CHEM 1105	Perspectives in Environmental Science	
EOS 2005	Biogeochemistry: An Analysis of Global Change	
EOS 2525	Marine Biogeochemistry	
EOS 2585	Ocean and Climate	
EOS 3020	Earth Climate History	
PHYS 2810	Atmospheric and Ocean Dynamics	
PHYS 3810	The Physics of Climate	
BIOL 2319	Biology of Marine Organisms	
BIOL 2333	Benthic Ecology	
BIOL 2327	Ecology	
BIOL 2581	Forest Ecology and Conservation	
One additional course from the molecular or environmental perspectives lists		1
At least one course from the advanced level (3000–3999) of either molecular or environmental perspectives courses		

Geochemical Concentration

Code	Title	Credits
CHEM 2050	Environmental Chemistry	1
CHEM 2510	Chemical Thermodynamics and Kinetics	1
CHEM 3100	Instrumental Analysis	1
Select two electives from the following: [f]		2
EOS 2005	Biogeochemistry: An Analysis of Global Change	
EOS 2165	Mountains to Trenches	
EOS 2585	Ocean and Climate	
EOS 3020	Earth Climate History	
EOS 3115	Research in Mineral Science	

f At least one elective must be at the advanced level (3000–3999).

Neurochemical Concentration

The Neurochemical Concentration consists of seven credits.

Chemistry majors completing the neurochemical concentration cannot also major in neuroscience.

Code	Title	Credits
BIOL 1102	Biological Principles II	1
or BIOL 1109	Scientific Reasoning in Biology	
CHEM 2260	Organic Chemistry II	1
or CHEM 2261	Organic Chemistry II with Research Laboratory	
CHEM 2320	Biochemistry	1
CHEM 2510	Chemical Thermodynamics and Kinetics	1
or CHEM 2520	Quantum Chemistry and Spectroscopy	
Select two electives from the following:		2

BIOL 2135	Neurobiology	
BIOL 2510	Neuropharmacology	
BIOL 2553	Neurophysiology	
BIOL 2566	Molecular Neurobiology	
One advanced neuroscience course (3000–3999)		1

Chemistry Minor

The minor consists of four chemistry courses at or above the intermediate level (2000–2969). One intermediate or advanced independent study can count toward the minor.

Interdisciplinary Majors

The chemistry department participates in the biochemistry and environmental studies programs, as well as in the interdisciplinary chemical physics major. See Interdisciplinary Majors (https://bowdoin-public.courseleaf.com/departments-programs/interdisciplinary-majors/) area for more information.

Additional Information

Additional Information and Department Policies

- Only one grade of D may be counted for the major or minor. This D must be offset by a grade of B or higher in another chemistry course also required for the major or minor.
- Generally, courses for the major or minor must be taken for regular letter grades (not Credit/D/Fail). Under special circumstances, however, a student may petition the department chair to allow one course required for the major or minor to be taken with the Credit/D/Fail grading option.
- With prior approval from the department chair, up to two transfer credits can count toward the major or minor.
- Majors may double-count two courses with another department or program with one exception: majors pursuing the educational concentration may double-count the four required education courses. Minors may double-count an unlimited number of courses with another department or program.
- Biochemistry majors may not declare a major or minor in chemistry. Chemistry majors completing the neurochemical concentration may not also major in neuroscience.

Advanced Placement/International Baccalaureate (AP/IB)

Students who received a minimum score of four on the Chemistry AP exam or a minimum score of five on the Chemistry IB exam are eligible to receive a credit and can count it toward the major or minor after completion of CHEM 2050 Environmental Chemistry, CHEM 2100 Chemical Analysis, CHEM 2250 Organic Chemistry I, CHEM 2400 Inorganic Chemistry, CHEM 2510 Chemical Thermodynamics and Kinetics, or CHEM 2520 Quantum Chemistry and Spectroscopy with a minimum grade of C-; however, credit is not given if the student places into or elects to take CHEM 1091 Introductory Chemistry and Quantitative Reasoning I, CHEM 1092 Introductory Chemistry and Quantitative Reasoning II, CHEM 1101 Introductory Chemistry I, CHEM 1102 Introductory Chemistry II or CHEM 1109 General Chemistry. Regardless of AP/IB score, all students must take the placement exam. In order to receive credit for advanced placement work, students must have their scores officially reported to the Office of the Registrar by the end of their sophomore year at Bowdoin.

Career Paths

The chemistry major can serve as preparation for many career paths after college, including the profession of chemistry, graduate studies in the sciences, medicine, secondary school teaching, and many fields in the business world. The department offers programs based on the interests and goals of the student; therefore, a prospective major should discuss their plans with the department as soon as possible. Regardless of career goals, students are encouraged to develop their critical thinking and problem-solving skills by participating in a collaborative student-faculty research project (Chemistry 2970–2999, 4000–4051, or summer research).

The department also offers an American Chemical Society-certified major in chemistry. The requirements for certification are met by taking additional courses in chemistry and other disciplines. Students interested in this certification program should consult their advisor and refer to guidelines found at acs.org/cpt (http://acs.org/cpt/).

Independent Study/Honors Projects

Students may engage in independent study at the intermediate (2970–2999) or advanced (4000–4051) level. Only one advanced level independent study or honors project can count as an elective toward the major. Majors pursuing honors in chemistry are required to register for CHEM 4050 during the first semester and CHEM 4051 during the second semester of their senior year, and attend weekly seminars/workshops on Fridays, 11:40 a.m. to 1:05 p.m., during both semesters.

Information for Incoming Students (p. 3)

Students must take the chemistry placement exam to enroll in any chemistry course numbered 1091 and higher. If students do not complete the chemistry placement exam in the summer prior to matriculation, they need to take the chemistry placement exam immediately and notify the department (https://www.bowdoin.edu/chemistry/) when they have completed the exam so that an assessment can be made prior to course registration. Placements are determined based on the result of the chemistry placement exam and other information, which includes the Quantitative Reasoning (QR) placement exam, physics placement exam (also strongly recommended for students interested in chemistry courses), SAT or ACT scores, and AP or IB scores.

Chemistry courses numbered between 1000-1090 are meant to fulfill the INS (Inquiry in the Natural Sciences) distribution degree requirement and assume no previous science background. They are appropriate for students who do not intend to take further courses in chemistry at Bowdoin. They do not require a placement in chemistry.

CHEM 1091 Introductory Chemistry and Quantitative Reasoning I is offered as an invitation-only fall-semester course and is intended for students with limited background in chemistry who will benefit from additional time devoted to improving quantitative skills and meets for three one-hour lecture sections per week, one three-hour laboratory per week, and one hour and a half problem solving/quantitative skills building session per week. It leads to CHEM 1092 Introductory Chemistry and Quantitative Reasoning II in the spring.

CHEM 1101 Introductory Chemistry I is offered only as a fall-semester course and is intended for students with limited to adequate backgrounds in chemistry and meets for a total of three lecture-hours

per week, and one three-hour laboratory per week. It leads to CHEM 1102 Introductory Chemistry II in the spring.

CHEM 1109 General Chemistry is a one-semester course, taught during both the fall and spring semesters, intended for students with solid high school chemistry preparation and meets for a total of three lecture-hours per week and one four-hour laboratory per week.

Chemistry courses at the 2000-level, which are open to students with the "CHEM 2000-level/CHEM 1109" or "CHEM 2000-level" placement, are appropriate for students with outstanding high-school chemistry preparation. These course options are CHEM 2250 Organic Chemistry I and CHEM 2100 Chemical Analysis in the fall semester and CHEM 2400 Inorganic Chemistry and CHEM 2050 Environmental Chemistry in the spring semester. While CHEM 2510 Chemical Thermodynamics and Kinetics and CHEM 2520 Quantum Chemistry and Spectroscopy are also entry points, students must also meet prerequisites in mathematics and physics to enroll in these courses. Students who start and complete a 2000-level chemistry course are not permitted to register concurrently or in a future semester for CHEM 1101 Introductory Chemistry I or CHEM 1109 General Chemistry. Students interested in 2000-level courses should contact the instructors to learn more about the course.

Summary of Placements in Chemistry

- CHEM 1091: permits registration in CHEM 1091 Introductory Chemistry and Quantitative Reasoning I only
- CHEM 1101: permits registration in CHEM 1101 Introductory Chemistry I only
- CHEM 1109/1101: permits registration in CHEM 1109 General Chemistry or CHEM 1101 Introductory Chemistry I (this placement indicates the student is on the border between these two entry points. Students are permitted to enroll in either course and should consult with the instructors to ensure proper entry to the curriculum)
- CHEM 1109: permits registration in CHEM 1109 General Chemistry only
- CHEM 2000-level/CHEM 1109: permits registration in Chemistry at the 2000-level or CHEM 1109 General Chemistry (this placement indicates the student is on the border between these two entry points. Students are permitted to enroll in either course and should consult with the instructors to ensure proper entry to the curriculum)
- CHEM 2000-level: permits registration in Chemistry at the 2000-level (this placement indicates that a student should enroll in a 2000-level chemistry course, CHEM 2250 Organic Chemistry I is the most common entry point)

Additional information: When deciding to begin with a 1000-level chemistry course or a 1000-level biology course during their first semester, many students find a grounding in chemistry helpful before beginning a course in biology. As a word of caution, some first-year students find it advantageous to wait until their sophomore year to start chemistry; however, this means they cannot take CHEM 2250 Organic Chemistry I until their junior year if they begin with introductory chemistry as a sophomore. Students who placed into MATH 1050 Quantitative Reasoning or PHYS 1093 Introduction to Quantitative Reasoning in the Physical Sciences need not take both and are strongly recommended to enroll in PHYS 1093 Introduction to Quantitative Reasoning in the Physical Sciences as this course provides the appropriate grounding for 1000-level science courses, as well as MATH 1600 Differential Calculus.

Courses

CHEM 1054 (a, INS) Chemistry in Art and Design
Brandon Tate.
Non-Standard Rotation. Fall 2023. Enrollment limit: 24.

Examines the intersections of chemical science with the visual and performing arts. Fundamental concepts of atomic structure, chemical bonding, and chemical reactions are introduced through discussions of the material composition of artists' tools and media. Selected topics include the molecular origin of color in pigments and dyes, the aging and weathering of architectural structures over time, the science behind the preservation and restoration of works of art, and the development of polymers for 3D printing. Laboratory activities include hands-on applications of the scientific method to answer questions about the chemistry of artistic media as well as the creation of an original work of art inspired by chemistry. Assumes no background in science. Not open to students who have credit for a chemistry course numbered 1000 or higher or who have placements in CHEM 1109, CHEM 2000 level, or CHEM 2000/1109.

Previous terms offered: Spring 2023.

CHEM 1055 (a, INS) Science of Food and Wine
Non-Standard Rotation. Enrollment limit: 24.

Methods of food and wine preparation and production emerged from essentially controlled scientific experiments, even if the techniques of cooking are often carried out without thought of the underlying physical processes at play. Considers the science behind food and wine using bread baking, cooking techniques, the role of microbes in our diet, and wine making and appreciation to explore the chemistry and biology that underlie our gastronomy. Molecular structures and complex interactions central to cooking and wine are examined in integrated laboratory exercises. Assumes no background in science. Not open to students who have credit for a chemistry course numbered 1090 or higher.

Previous terms offered: Spring 2021.

CHEM 1057 (a, INS) Chemistry for the Common Good
Non-Standard Rotation. Enrollment limit: 24.

Scientific reasoning and public engagement are parts of civic responsibility, necessary in our pursuit of the common good. From concerns about equal access to clean air and water to realization of the devastating effects of the opioid crisis, future leaders in the community who plan to engage in meaningful discussions of society's pressing issues must develop an appreciation of the science that underlies these issues. This course will develop students' knowledge of chemistry through examination of a broad range of community issues, discovering how knowledge of chemistry is integrated into both our understanding and proposed solutions to today's problems. Students work together to actively explore related chemical concepts and the process of scientific inquiry in integrated lab exercises. Throughout the semester, students reflect, discuss, and reevaluate how their growing knowledge of chemistry impacts their own commitments and approaches to community activities. Assumes no background in science. Not open to students who have credit for a Chemistry course numbered 1000 or higher or who have placements in CHEM 1109, CHEM 2000 level, or CHEM 2000/1109.

Previous terms offered: Spring 2020.

CHEM 1058 (a, INS) Drug Discovery
Non-Standard Rotation. Enrollment limit: 25.

The process of drug discovery of medicinal compounds has evolved over millennia, from the shaman's use of medicinal herbs to the highly evolved techniques of rational design and high-throughput screening used by today's pharmaceutical industry. Examines past and present approaches to drug discovery, with an emphasis on the natural world as a source of drugs, historical examples of drug discovery, and the experiments undertaken to validate a drug. Encourages students to take initial steps to identify novel therapeutics and to directly compare conventional versus herbal remedies in integrated laboratory exercises. Assumes no background in science. Not open to students who have credit for a chemistry course numbered 1090 or higher.

Previous terms offered: Spring 2021, Fall 2019.

CHEM 1061 (a, INS) The World at Nanoscale using Computers in Chemistry
Sanoj ..
Every Fall. Fall 2023. Enrollment limit: 50.

Computers can offer interactive learning experiences, visualization, simulations, and data analysis tools, making the subject more accessible and enjoyable. Students learn about nanoscale forces, using hands-on software exploration to run simple simulations (self-assembly, dissolving salt in water, buffer preparation, free energy estimations, material design for quantum computations) and undertake molecular visualization of their systems. Students learn animation and cinematic representations to explain complex concepts and dynamic processes. All computer codes and other materials will be provided. Assumes no background in science. Two hours lecture and 1-hour hands-on lab. Not open to students who have credit for a chemistry course numbered 1090 or higher.

CHEM 1091 (a, INS) Introductory Chemistry and Quantitative Reasoning I
Michael Danahy; Ren Bernier; Abigail Snipe-Bushey.
Every Fall. Fall 2023. Enrollment limit: 15.

The first course in a two-semester introductory college chemistry sequence covering the same content as Chemistry 1101/1102 with additional instruction focused on developing quantitative reasoning and problem-solving skills in the context of learning chemistry. Topics include the properties of matter, atomic and molecular structure, quantum and periodic trends, chemical bonding, intermolecular forces, stoichiometry, and aqueous solutions. Three hours of lecture, mandatory one-hour problem-solving session, and three hours of laboratory work per week. To ensure proper placement, students must take the chemistry placement examination prior to registration and must be recommended for placement in Chemistry 1091. Not open to students who have taken Chemistry 1101, 1102, or 1109. Students continuing in chemistry take Chemistry 1092 as their next chemistry course.

Prerequisites: Placement in CHEM 1091.

Previous terms offered: Fall 2022, Fall 2021, Fall 2020, Fall 2019.

CHEM 1092 (a, INS, MCSR) Introductory Chemistry and Quantitative Reasoning II
Michael Danahy; Inoka Pathiraja; Ren Bernier; Abigail Snipe-Bushey.
Every Spring. Spring 2024. Enrollment limit: 15.

The second course in a two-semester introductory college chemistry sequence that follows Chemistry 1091. Incorporates additional instruction focused on developing quantitative reasoning and problem-solving skills in the context of learning chemistry. Topics include gases, properties of solutions, thermodynamics and thermochemistry, kinetics, equilibrium, electrochemistry, and acid-base chemistry. Three hours of lecture, mandatory one-hour problem-solving session, and four hours of laboratory work per week.

Prerequisites: CHEM 1091.

Previous terms offered: Spring 2023, Spring 2022, Spring 2021, Spring 2020.

CHEM 1093 (a, MCSR) Introduction to Quantitative Reasoning in the Physical Sciences
Liz McCormack.
Every Fall. Fall 2023. Enrollment limit: 20.

Climate science. Quantum Physics. Bioengineering. Rocket science. Who can understand it? Anyone with high school mathematics (geometry and algebra) can start. Getting started in physics requires an ability to mathematically describe real world objects and experiences. Prepares students for additional work in physical science and engineering by focused practice in quantitative description, interpretation, and calculation. Includes hands-on measurements, some introductory computer programming, and many questions about the physics all around us. Registration for this course is by placement only. To ensure proper placement, students must have taken the physics placement examination prior to registering for Physics 1093. (Same as: PHYS 1093)

Prerequisites: Placement in PHYS 1093.

Previous terms offered: Fall 2022, Fall 2021, Fall 2020.

CHEM 1101 (a, INS) Introductory Chemistry I
Brandon Tate; Amnon Ortoll-Bloch; Ren Bernier; Abigail Snipe-Bushey.
Every Fall. Fall 2023. Enrollment limit: 45.

The first course in a two-semester introductory college chemistry sequence. Introduction to the states of matter and their properties, stoichiometry and the mole unit, properties of gases, thermochemistry, atomic structure, and periodic properties of the elements. Lectures, review sessions, and four hours of laboratory work per week. To ensure proper placement, students must take the chemistry placement examination and must be recommended for placement in Chemistry 1101. Students continuing in chemistry take Chemistry 1102, not Chemistry 1109, as their next chemistry course.

Prerequisites: Placement in CHEM 1101 or Placement in CHEM 1109/1101.

Previous terms offered: Fall 2022, Fall 2021, Fall 2020, Fall 2019.

CHEM 1102 (a, INS, MCSR) Introductory Chemistry II
Inoka Pathiraja; Sanoj .; Sean Lutz; Ren Bernier; Abigail Snipe-Bushey.
Every Spring. Spring 2024. Enrollment limit: 40.

The second course in a two-semester introductory college chemistry sequence. Introduction to chemical bonding and intermolecular forces, characterization of chemical systems at equilibrium and spontaneous processes, the rates of chemical reactions, and special topics. Lectures, review sessions, and four hours of laboratory work per week. Students who have taken Chemistry 1109 may not take Chemistry 1102 for credit.

Prerequisites: CHEM 1101.

Previous terms offered: Spring 2023, Spring 2022, Spring 2021, Spring 2020.

CHEM 1105 (a, INS, MCSR) Perspectives in Environmental Science
Phil Camill; Brandon Tate; Shana Stewart Deeds.
Every Spring. Spring 2024. Enrollment limit: 35.

Understanding environmental challenges requires scientific knowledge about the different spheres of the Earth -- land, water, air, and life -- and how they interact. Presents integrated perspectives across the fields of biology, chemistry, and earth and oceanographic science to examine the scientific basis for environmental change from the molecular to the global level. Foundational principles are developed to address major course themes, including climate change, energy, soil/air/water pollution, chemical exposure and risk, land use change, and biodiversity loss. Laboratory sessions consist of local field trips, laboratory experiments, group research, case study exercises, and discussions of current and classic scientific literature. (Same as: ENVS 2201, BIOL 1158)

Prerequisites: BIOL 1101 or BIOL 1109 or CHEM 1091 - 2260 or PHYS 1130 or PHYS 1140 or EOS 1105 or EOS 1305 (same as ENVS 1104) or EOS 1505 (same as ENVS 1102) or EOS 2005 (same as ENVS 2221) or EOS 2115 or EOS 2335 or EOS 2345 (same as ENVS 2270) or EOS 2365 or EOS 2525 (same as ENVS 2251) or EOS 2535 or EOS 2585 (same as ENVS 2282) or ENVS 1101.

Previous terms offered: Spring 2023, Spring 2022, Spring 2021, Spring 2020.

CHEM 1109 (a, INS, MCSR) General Chemistry
Inoka Pathiraja; Michael Henderson; Ren Bernier; Abigail Snipe-Bushey; Danielle Dube; Dani Calles; Denny Tesfa.
Every Semester. Fall 2023; Spring 2024. Enrollment limit: 35.

A one-semester introductory chemistry course. Introduction to models of atomic structure, chemical bonding, and intermolecular forces; characterization of chemical systems at equilibrium and spontaneous processes; the rates of chemical reactions; and special topics. Lectures, review sessions, and four hours of laboratory work per week. Students who have taken Chemistry 1102 may not take Chemistry 1109 for credit. To ensure proper placement, students must take the chemistry placement examination and must be recommended for placement in Chemistry 1109.

Prerequisites: Placement in CHEM 1109/1101 or Placement in CHEM 1109 or Placement in CHEM 2000/1109.

Previous terms offered: Spring 2023, Fall 2022, Spring 2022, Fall 2021, Spring 2021, Fall 2020, Spring 2020, Fall 2019.

CHEM 2050 (a, INS) Environmental Chemistry
Brandon Tate; Kurt Luthy.
Every Other Spring. Spring 2024. Enrollment limit: 20.

Focuses on two key processes that influence human and wildlife exposure to potentially harmful substances, chemical speciation and transformation. Equilibrium principles as applied to acid-base, complexation, precipitation, and dissolution reactions are used to explore organic and inorganic compound speciation in natural and polluted waters; quantitative approaches are emphasized. Weekly laboratory sections are concerned with the detection and quantification of organic and inorganic compounds in air, water, and soils/sediments. (Same as: ENVS 2255, EOS 2325)

Prerequisites: CHEM 1092 or CHEM 1102 or CHEM 1109 or CHEM 2000 - 2969 or Placement in CHEM 2000 level or Placement in CHEM 2000/1109.

Previous terms offered: Spring 2022, Spring 2020.

CHEM 2100 (a, INS, MCSR) Chemical Analysis
Sanoj .; Kurt Luthy.
Every Fall. Fall 2023. Enrollment limit: 20.

Methods of separating and quantifying inorganic and organic compounds using volumetric, spectrophotometric, electrometric, and chromatographic techniques are covered. Chemical equilibria and the statistical analysis of data are addressed. Lectures and four hours of laboratory work per week.

Prerequisites: CHEM 1092 or CHEM 1102 or CHEM 1109 or CHEM 2000 - 2969 or Placement in CHEM 2000 level or Placement in CHEM 2000/1109.

Previous terms offered: Fall 2022, Fall 2021, Fall 2020, Fall 2019.

CHEM 2250 (a) Organic Chemistry I
Richard Broene; Benjamin Gorske; Michael Danahy; Paulette Messier; Abigail Snipe-Bushey; Inoka Pathiraja.
Every Fall. Fall 2023. Enrollment limit: 35.

Introduction to the chemistry of the compounds of carbon. Describes bonding, conformations, and stereochemistry of small organic molecules. Reactions of hydrocarbons, alkyl halides, and alcohols are discussed. Kinetic and thermodynamic data are used to formulate reaction mechanisms. Lectures, review sessions, and four hours of laboratory work per week.

Prerequisites: CHEM 1092 or CHEM 1102 or CHEM 1109 or CHEM 2000 - 2969 or Placement in CHEM 2000 level or Placement in CHEM 2000/1109.

Previous terms offered: Fall 2022, Fall 2021, Fall 2020, Fall 2019.

CHEM 2260 (a) Organic Chemistry II
Paulette Messier; Michael Danahy; Richard Broene; Martha Black; Kurt Luthy.
Every Spring. Spring 2024. Enrollment limit: 30.

Continuation of the study of the compounds of carbon. Highlights the reactions of aromatic, carbonyl-containing, and amine functional groups. Mechanistic reasoning provides a basis for understanding these reactions. Skills for designing logical synthetic approaches to complex organic molecules are developed. Lectures, review sessions, and four hours of laboratory work per week.

Prerequisites: CHEM 2250.

Previous terms offered: Spring 2023, Spring 2022, Spring 2021, Spring 2020.

CHEM 2261 (a) Organic Chemistry II with Research Laboratory
Paulette Messier; Benjamin Gorske.
Non-Standard Rotation. Spring 2024. Enrollment limit: 08.

This laboratory section will differ from the others associated with this course by focusing on the conduct of actual research, in which students will design, construct, and test new enzyme mimics intended to facilitate to the discovery of new medicines. As in the other laboratory sections, students will learn to generate experimental plans based on those found in the literature, execute experiments efficiently and safely, analyze and explain their data, and generate appropriate reports of their activities. The assessment and time expectations both in and outside of the laboratory are designed to be identical to those of the other laboratory sections, while giving the participants a perspective on modern chemistry research techniques and allowing them to contribute to advancing an important scientific field.

Prerequisites: CHEM 2250.

CHEM 2320 (a, MCSR) Biochemistry
Danielle Dube; Dani Calles; Kate Farnham.
Every Spring. Spring 2024. Enrollment limit: 36.

Focuses on the chemistry of living organisms. Topics include structure, conformation, and properties of the major classes of biomolecules (proteins, nucleic acids, carbohydrates, and lipids); enzyme mechanisms, kinetics, and regulation; metabolic transformations; energetics and metabolic control. Lectures and four hours of laboratory work per week. This course satisfies a requirement for the biochemistry major. (Same as: BIOC 2320)

Prerequisites: CHEM 2260 or CHEM 2261.

Previous terms offered: Spring 2023, Spring 2022, Spring 2021, Spring 2020.

CHEM 2400 (a, INS, MCSR) Inorganic Chemistry
Amnon Ortoll-Bloch; Denny Tesfa.
Every Spring. Spring 2024. Enrollment limit: 24.

An introduction to the chemistry of the elements with a focus on chemical bonding, periodic properties, and coordination compounds. Topics in solid state, bioinorganic, and environmental inorganic chemistry are also included. Provides a foundation for further work in chemistry and biochemistry. Lectures and four hours of laboratory work per week.

Prerequisites: CHEM 1092 or CHEM 1102 or CHEM 1109 or CHEM 2000 - 2969 or Placement in CHEM 2000 level or Placement in CHEM 2000/1109.

Previous terms offered: Spring 2023, Spring 2022, Spring 2021, Spring 2020.

CHEM 2510 (a, INS, MCSR) Chemical Thermodynamics and Kinetics
Sean Lutz; Martha Black.
Every Fall. Fall 2023. Enrollment limit: 36.

Thermodynamics and its application to chemical changes and equilibria that occur in the gaseous, solid, and liquid states. The behavior of systems at equilibrium and chemical kinetics are related to molecular properties by means of statistical mechanics and the laws of thermodynamics. Lectures and four hours of laboratory work per week. Mathematics 1800 is recommended.

Prerequisites: Three of: either CHEM 1092 or CHEM 1102 or CHEM 1109 or CHEM 2000 - 2969 or Placement in CHEM 2000 level or Placement in CHEM 2000/1109 and MATH 1700 or higher or Placement in MATH 1800 (M) or Placement in MATH 2020 or 2206 (M) or Placement in 2000, 2020, 2206 (M) and either PHYS 1130 or PHYS 1140.

Previous terms offered: Fall 2022, Fall 2021, Fall 2020, Fall 2019.

CHEM 2520 (a, INS, MCSR) Quantum Chemistry and Spectroscopy
Sean Lutz; Martha Black.
Every Spring. Spring 2024. Enrollment limit: 12.

Development and principles of quantum chemistry with applications to atomic structure, chemical bonding, chemical reactivity, and molecular spectroscopy. Lectures and four hours of laboratory work per week. Mathematics 1800 is recommended. Note: Chemistry 2510 is not a prerequisite for Chemistry 2520 .

Prerequisites: Three of: either CHEM 1092 or CHEM 1102 or CHEM 1109 or CHEM 2000 - 2969 or Placement in CHEM 2000 level or Placement in CHEM 2000/1109 and MATH 1700 or higher or Placement in MATH 1800 (M) or Placement in MATH 2020 or 2206 (M) or Placement in 2000, 2020, 2206 (M) and PHYS 1140.

Previous terms offered: Spring 2023, Spring 2022, Spring 2021, Spring 2020.

CHEM 2550 (a, INS, MCSR) Introduction to Computational Chemistry
Non-Standard Rotation. Enrollment limit: 35.

An introduction to theories, models, and methods in computational chemistry. Computational modeling is used to explain observed chemical phenomena, predict properties of hypothetical chemical systems, and design or propose molecules and/or materials with specific properties. Depending on the nature of the chemical system and the information desired, different approximations and computational approaches are needed and explored in class. Students use existing computational modeling codes running on the Bowdoin high-performance computing grid to apply theories and methods to chemical problems. Three hours of lecture and one hour open lab session per week.

Prerequisites: Three of: either CHEM 2250 or CHEM 2400 or CHEM 2520 or PHYS 3140 and PHYS 1140 and MATH 1700 - 2969 or Placement in MATH 1800 (M) or Placement in MATH 1808 {2108} (M) or Placement in MATH 2020 or 2206 (M) or Placement in 2000, 2020, 2206 (M).

Previous terms offered: Fall 2021, Spring 2021.

CHEM 3050 (a, INS) Environmental Fate of Organic Chemicals
Non-Standard Rotation. Enrollment limit: 16.

More than 100,000 synthetic chemicals are currently in daily use. In order to determine the risk posed to humans and ecosystems, the extent and routes of chemical exposure must be understood and anticipated. Addresses the fate of organic chemicals following their intentional or unintentional release into the environment. Why do these chemicals either persist or break down, and how are they distributed between surface water, ground water, soil, sediments, biota, and air? Analysis of chemical structure used to gain insight into molecular interactions that determine the various chemical transfer and transformation processes, while emphasizing the quantitative description of these processes. (Same as: ENVS 3905)

Prerequisites: CHEM 2250.

Previous terms offered: Fall 2020.

CHEM 3055 (a) Catalysis in Sustainable Chemical Processes
Non-Standard Rotation. Enrollment limit: 16.

Catalysis is a versatile tool in the development of sustainable chemical processes and renewable alternatives to fossil fuels and petrochemicals. The introduction of catalysis to an industrial chemical process provides opportunities for improved energy efficiency, reduced waste, conservation of scarce natural resources, lower costs, and greater selectivity, potentially facilitating chemical transformations that are otherwise inaccessible. This course covers essential concepts in transition state theory and chemical kinetics and the application of catalysis to outstanding problems in global chemical sustainability. Approaches to the design, characterization, and optimization of inorganic, organic, and biological catalysts are discussed in the context of applications including chemical energy storage, carbon capture and utilization, biomass conversion, sustainable plastics and polymers, and environmental remediation. (Same as: ENVS 3904)

Prerequisites: CHEM 2250.

Previous terms offered: Fall 2022.

CHEM 3100 (a) Instrumental Analysis
Sanoj ..
Every Other Spring. Spring 2024. Enrollment limit: 15.

Theoretical and practical aspects of instrumental techniques, including nuclear magnetic resonance spectroscopy, infrared spectroscopy, Raman spectroscopy, and mass spectrometry are covered, in conjunction with advanced chromatographic methods. Applications of instrumental techniques to the analysis of biological and environmental samples are covered. Lectures and two hours of laboratory work per week.

Prerequisites: CHEM 2100.

Previous terms offered: Spring 2022, Spring 2020.

CHEM 3200 (a) Advanced Organic Chemistry: Organometallic Chemistry
Non-Standard Rotation. Enrollment limit: 15.

In-depth study of compounds containing metal-carbon bonds and their reactions, with emphasis on synthesis and spectroscopy. A mechanistic approach is used to discover how these species act as catalysts or intermediates in synthetic organic reactions. Special techniques for handling these often sensitive molecules are introduced.

Prerequisites: Two of: either CHEM 2260 or CHEM 2261 and CHEM 2400.

Previous terms offered: Fall 2019.

CHEM 3250 (a) Structure Determination in Organic Chemistry
Richard Broene.
Non-Standard Rotation. Fall 2023. Enrollment limit: 12.

The theory and application of spectroscopic techniques useful for the determination of the molecular structures of organic molecules are discussed. Mass spectrometry and infrared, ultraviolet-visible, and nuclear magnetic resonance (NMR) spectroscopies are applied to structure elucidation. Heavy emphasis is placed on applications of multiple-pulse, Fourier transform NMR spectroscopic techniques. Lectures and at least two hours of laboratory work per week.

Prerequisites: CHEM 2260 or CHEM 2261.

Previous terms offered: Fall 2021.

CHEM 3270 (a) Biomimetic and Supramolecular Chemistry
Non-Standard Rotation. Enrollment limit: 15.

A guided exploration of the primary scientific literature concerning weak covalent and noncovalent interactions that collectively determine the three-dimensional structures of biomimetic and foldameric molecules and that govern the aggregation of molecules into discrete multi-molecular assemblies. Surveys practical applications in biochemical investigation, catalysis, and medicine, as well as in the young but rapidly expanding sciences of molecular and nanostructural engineering. NOTE: There is NO LABORATORY WORK associated with this course. The required designated lab is a required discussion session.

Prerequisites: CHEM 2260 or CHEM 2261.

Previous terms offered: Fall 2022, Spring 2022, Spring 2021.

CHEM 3310 (a) Chemical Biology
Danielle Dube.
Every Other Fall. Spring 2024. Enrollment limit: 16.

The power of organic synthesis has had a tremendous impact on understanding of biological systems. Examines case studies in which synthetically derived small molecules have been used as tools to tease out answers to questions of biological significance. Topics include synthetic strategies that have been used to make derivatives of the major classes of biomolecules (nucleic acids, proteins, carbohydrates, and lipids) and the experimental breakthroughs these molecules have enabled (e.g., polymerase-chain reaction, DNA sequencing, microarray technology). Emphasis on current literature, experimental design, and critical review of manuscripts.

Prerequisites: CHEM 2320.

Previous terms offered: Spring 2023, Fall 2021, Fall 2020.

CHEM 3320 (a, MCSR) Molecular Biophysics
Michael Henderson.
Non-Standard Rotation. Fall 2023. Enrollment limit: 16.

This course will take a quantitative approach relying on principles from thermodynamics, kinetics and mechanics to explore how the structure, function and assembly of molecular components like lipids, proteins and DNA govern biological systems and their physical-chemical behavior. Topics will include: (1) lipid membrane organization and lipid-protein interactions, (2) transport mechanisms, (3) compartmentalization through liquid-liquid phase separation, and (4) mechanisms of force generation through molecular motors and cytoskeletal polymers. Emphasis throughout the course will be placed on experimental methodologies employed in these topic areas such as optical microscopy, single-molecule approaches, and force spectroscopies. The format will be a combination of lectures, discussions and journal article presentations. (Same as: BIOC 3320)

Prerequisites: Two of: PHYS 1130 and CHEM 2320 (same as BIOC 2320).

CHEM 3400 (a) Advanced Inorganic Chemistry
Amnon Ortoll-Bloch.
Every Other Spring. Spring 2024. Enrollment limit: 12.

Inorganic chemistry is incredibly diverse and wide-ranging in scope. Symmetry, spectroscopy, and quantum-based theories and computational methods are employed to gain insight into the molecular and electronic structures and reaction mechanisms of inorganic compounds. Examples from the current literature emphasized, including topics in inorganic photochemistry and biochemistry. Chemistry 2520 is recommended.

Prerequisites: CHEM 2400.

Previous terms offered: Spring 2023, Spring 2021.

CHEM 3510 (a) Reactivity and Kinetics
Non-Standard Rotation. Enrollment limit: 15.

Explores reactivity and kinetics from a physical chemistry perspective. We will survey theories and applications to model observed synthetic, gas phase, surface, and biological reactions. In particular, we will utilize a molecular picture to rationalize current and past discoveries in chemistry. Planned topics include aspects of the isotope effect and tunneling in catalysis, potential energy surfaces and molecular dynamic models, photochemistry and conical intersections, reaction dynamics and molecular beam experiments, enzymology, surface catalysis, polymer-binding, and charge-transfer models. Emphasis will be placed on reading and discussing scientific literature.

Prerequisites: CHEM 2510.

Previous terms offered: Spring 2020.