

CHEMISTRY

Chair: Louis Kuo - Fall 2017

Chair: Julio de Paula - Spring 2018

Administrative Coordinator: Amy Timmins

The Department of Chemistry curriculum serves four groups of students: chemistry and biochemistry/molecular biology majors; biology, engineering, and environmental studies majors; students planning to apply to professional schools in the health sciences; and nonscience majors satisfying their scientific and quantitative reasoning General Education requirement.

Special Programs

The departments of chemistry and biology offer an interdisciplinary biochemistry/molecular biology major. See Biochemistry and Molecular Biology.

Resources for Nonmajors

CHEM 100 Perspectives in Environmental Chemistry and CHEM 105 Perspectives in Nutrition are specifically designed to help nonscience majors learn chemistry and relate it to the world around them.

Facilities

The Olin Center for Physics and Chemistry has more than 40,000 square feet of classroom, laboratory, and study space. Facilities and equipment used by the chemistry department include a lecture-demonstration theatre; a well-equipped biochemistry laboratory; modern scientific instrumentation (nuclear magnetic resonance spectrometer, infrared spectrometers, gas chromatograph/mass spectrometer, high-pressure liquid chromatograph, scanning electron microscope, Raman microscope, powder and single-crystal X-ray diffractometers, molecular modeling workstations, etc.); a data analysis room; special laboratories for general chemistry, organic chemistry, and advanced physical and inorganic chemistry; and research laboratories for collaborative work between students and faculty.

The Major Program

The Department of Chemistry provides a flexible, challenging curriculum to accommodate and encourage a diversified approach to the major. Following a core of required courses in general, organic, and physical chemistry, including laboratories, students select advanced courses from several electives.

In all chemistry courses, instructors encourage students to think for themselves and work independently. This is accomplished in some classes by having students work at the blackboard in small discussion groups to solve problems. In other courses, students survey chemical literature to make class presentations or write papers to discuss the nature of the work under study.

All students are encouraged to participate in research with a faculty member at the first opportunity, which may be as early as the sophomore year. The department uses research not only to foster independence of thought but also as a means of teaching students to teach themselves. Although the emphasis is on educating students, projects explore current areas of research and are often supported by grants. Frequently, projects result in publications coauthored by students and faculty.

Since the department's curriculum is regularly reviewed and approved by the Committee on Professional Training of the American Chemical Society (ACS), a student may select the specific set of courses that leads to an ACS-certified major. Students also have the option of meeting the

major requirements with courses that more closely reflect their particular interests and more optimally prepare them for certain advanced fields of study. Students who expect to attend a professional school after graduation (medicine, dentistry, pharmacy, and so on) will find that the flexible chemistry major curriculum more than meets their needs. A chemistry major may also elect to complete a series of education and certification courses and teach chemistry at the high school level following graduation.

Major Requirements

A minimum of 42 semester credits in chemistry, plus courses in mathematics and physics, distributed as follows:

General Chemistry

- CHEM 110 General Chemistry I
- CHEM 120 General Chemistry II

Organic Chemistry

- CHEM 210 Organic Chemistry I
- CHEM 220 Organic Chemistry II

Physical Chemistry

- CHEM 310 Physical Chemistry: Thermodynamics and Kinetics
- CHEM 320 Physical Chemistry: Statistical Mechanics and Quantum Chemistry

Advanced Laboratory

- CHEM 365 Physical Chemistry Laboratory
- CHEM 366 Inorganic Chemistry Laboratory

Advanced Chemistry

- CHEM 405 Chemistry Seminar
- CHEM 420 Advanced Inorganic Chemistry
- Four semester credits of electives selected from the following:

CHEM 305	Aquatic Chemistry
CHEM 330	Structural Biochemistry
CHEM 335	Metabolic Biochemistry
CHEM 415	Nanomaterials Chemistry
CHEM 421	Neurochemistry
CHEM 443	Medicinal Organic Chemistry
CHEM 462	Advanced Organic Synthesis
CHEM 464	Biomolecular NMR Spectroscopy
PHYS 201	Experimental Methods in the Physical Sciences

Mathematics

- MATH 131 Calculus I
- MATH 132 Calculus II

Physics

One of the following sequences is required:

- PHYS 141 Introductory General Physics I and PHYS 142 Introductory General Physics II

- PHYS 151 Physics I: Motion and PHYS 142 Introductory General Physics II
- PHYS 151 Physics I: Motion, PHYS 152 Physics II: Waves and Matter, and PHYS 251 Physics III: Electromagnetism

For an ACS-certified major, in addition to the above requirements, the student must also complete the following:

CHEM 330 Structural Biochemistry or CHEM 335 Metabolic Biochemistry

Four additional semester credits at the 300 or 400 level (higher than CHEM 310 Physical Chemistry: Thermodynamics and Kinetics).

A suitable combination of CHEM 299 Independent Study, CHEM 480 Senior Research, CHEM 499 Independent Research, PHYS 201 Experimental Methods in the Physical Sciences, and off-campus or summer research for a total of 400 laboratory contact hours beyond the introductory chemistry laboratory.

Minor Requirements

A minimum of 28 semester credits (six courses) taken for a grade, including the following:

General Chemistry

- CHEM 110 General Chemistry I
- CHEM 120 General Chemistry II

Organic Chemistry

- CHEM 210 Organic Chemistry I
- CHEM 220 Organic Chemistry II
- Eight semester credits of chemistry courses at the 300 or 400 level in at least two different subdisciplines. Students may use a maximum of 4 semester credits from the CHEM 310 Physical Chemistry: Thermodynamics and Kinetics and CHEM 320 Physical Chemistry: Statistical Mechanics and Quantum Chemistry sequence and a maximum of 4 semester credits from the CHEM 330 Structural Biochemistry and CHEM 335 Metabolic Biochemistry sequence to meet minor requirements.

For students who have earned a 5 on the AP Chemistry examination, the CHEM 110 requirement and associated credits will be waived.

Honors and Senior Research

Students are especially encouraged to do senior-level thesis research. Students who have distinguished themselves academically through the senior year (GPA of 3.500 or higher in Chemistry) are also eligible for honors in Chemistry. Students not qualifying for the honors program may elect to participate in the senior research program. In both programs, each student proposes a research project in consultation with a faculty member, presents the proposal to the department in a seminar, performs the laboratory work, prepares a written thesis, and defends the thesis orally before the department's faculty.

Faculty

Barbara A. Balko. Associate professor of chemistry. Physical chemistry. PhD 1991 University of California at Berkeley. AB 1984 Bryn Mawr College.

Anne K. Bentley. Associate professor of chemistry. General, inorganic, and materials chemistry; nanotechnology. PhD 2005 University of Wisconsin at Madison. BA 1997 Oberlin College.

Julio C. de Paula. Professor of chemistry, chair of the Department of Chemistry (spring). Physical chemistry, biophysical chemistry, nanotechnology. PhD 1987 Yale University. BA 1982 Rutgers University.

Casey M. Jones. Assistant professor of chemistry. Organic chemistry, surface chemistry. PhD, MA 2010 Princeton University. BA 2005 Reed College.

Louis Y. Kuo. Professor of chemistry, chair of the Department of Chemistry (fall). Organometallic/bioorganic chemistry. PhD 1989 Northwestern University. BS 1984 Harvey Mudd College.

Janis E. Lochner. Dr. Robert B. Pamplin Jr. Professor of Science, director of the Biochemistry and Molecular Biology Program (spring). Biochemistry. PhD 1981 Oregon Health Sciences University. BS 1976 Allegheny College.

Nikolaus M. Loening. Professor of chemistry. Physical chemistry, biophysical chemistry. PhD 2001, MPhil 1998 University of Cambridge. BS 1997 Harvey Mudd College.

Courses

CHEM 100 Perspectives in Environmental Chemistry

Faculty: de Paula, Bentley, Chemistry Faculty

Content: General and organic chemistry concepts developed for a more thorough understanding of chemically related environmental issues such as meeting energy needs (including through nuclear energy), atmospheric pollution (the greenhouse effect, stratospheric ozone depletion, photochemical smog, acid rain), toxicology, and plastics. Lecture, laboratory.

Prerequisites: QR 101 or equivalent.

Usually offered: Annually, spring semester.

Semester credits: 5.

CHEM 105 Perspectives in Nutrition

Faculty: Lochner, Chemistry Faculty

Content: The fundamental basis of human nutritional needs and contemporary controversies in nutrition. Extracting energy from carbohydrates, fats, and proteins; essential amino acids and the cellular synthesis of proteins; water-soluble vitamins in major nutrient metabolism; biological function of fat-soluble vitamins; physiological roles of minerals. Readings on contemporary controversies in nutrition including the relationship between diet and disease. Lecture, laboratory.

Prerequisites: None.

Usually offered: Annually, fall semester.

Semester credits: 4.

CHEM 110 General Chemistry I

Faculty: Balko, Bentley, de Paula, Jones, Kuo, Loening, Chemistry Faculty

Content: Introduction to the general principles of chemistry required for students planning a professional career in chemistry, a related science, the health professions, or engineering. Stoichiometry, atomic structure, chemical bonding and geometry, thermochemistry, gases, types of chemical reactions, statistics. Weekly laboratory exercises emphasizing qualitative and quantitative techniques that complement the lecture material. Lecture, discussion, laboratory.

Prerequisites: QR 101 or equivalent. Previous high school chemistry not required.

Usually offered: Annually, fall semester.

Semester credits: 5.

CHEM 114 The Origins of Life in the Universe

Faculty: Clifton, Loening, Safran, Tuft

Content: Processes of stellar evolution and planet formation that set the stage for life on Earth. Theories and evidence from diverse scientific disciplines on the origins of life and how physical and chemical aspects of the environment contributed to the emergence and transformations of life-forms. Scientific evaluation of the possibility of extraterrestrial life. Attention is devoted both to the processes and content of scientific discovery. Lecture, discussion, laboratory. Cross-listed with BIO 114, GEOL 114, and PHYS 114. Not applicable toward any major.

Prerequisites: QR 101 or equivalent.

Usually offered: Alternate Years, spring semester.

Semester credits: 4.

CHEM 120 General Chemistry II

Faculty: Balko, Bentley, de Paula, Jones, Kuo, Loening, Chemistry Faculty

Content: Continuation of General Chemistry I. Chemical equilibrium, kinetics, thermochemistry, thermodynamics, electrochemistry, inorganic chemistry. Weekly laboratory exercises emphasizing quantitative techniques that complement the lecture material. Lecture, discussion, laboratory.

Prerequisites: CHEM 110 or equivalent.

Usually offered: Annually, spring semester.

Semester credits: 5.

CHEM 210 Organic Chemistry I

Faculty: Jones, Kuo

Content: The basic principles of organic chemistry from a mechanistic perspective. Bonding (Lewis structures, atomic and molecular orbitals); stereochemistry (chiral compounds, enantiomers, diastereomers, conformers, optical activity, Fischer projections); nomenclature; chemistry of alkanes (free-radical substitution, reaction-coordinate energy diagrams, asymmetric induction); chemistry of alkyl halides, alcohols, ethers (substitution and elimination reactions, carbocations, pKa, nucleophilicity, leaving groups, kinetics); infrared (IR) and nuclear magnetic resonance (NMR) spectroscopy; chemistry of alkenes (addition and elimination reactions, oxidation and reduction, hydroboration, inductive and resonance effects of substituents, regio- and stereoselectivity); chemistry of alkynes (acidity, addition reactions); introduction to organometallic compounds. Lecture, discussion, laboratory.

Prerequisites: CHEM 120.

Restrictions: Sophomore standing required.

Usually offered: Annually, fall semester.

Semester credits: 5.

CHEM 220 Organic Chemistry II

Faculty: Jones, Kuo

Content: Chemistry of aldehydes and ketones (reactions at and adjacent to the carbonyl group, enolization, conjugate addition, oxidation, reduction). Lecture, conference, laboratory. Synthesis, chemistry of carboxylic acids and derivatives (pKa of acids, nucleophilic substitution of derivatives, acyl chlorides, esters, amides, anhydrides, nitriles). Carbohydrates (stereochemistry, aldoketoses, aldopentoses, aldohexoses, ketosugars, derivatives, furanose and pyranose forms, reducing and nonreducing sugars, disaccharides and polysaccharides); fats and oils; aromatic hydrocarbons (benzene, resonance and molecular orbital approaches, electrophilic and nucleophilic aromatic substitution); aromatic nitrogen and oxygen chemistry (diazotization, synthesis); chemistry of amines, amino acids, peptides, proteins, DNA; other topics. Lecture, discussion, laboratory.

Prerequisites: CHEM 210.

Restrictions: Sophomore standing required.

Usually offered: Annually, spring semester.

Semester credits: 5.

CHEM 244 Practicum / Internship

Faculty: Chemistry Faculty

Content: Internship or practicum to be arranged with instructor.

Prerequisites: None.

Restrictions: Sophomore standing and consent required.

Usually offered: Annually, fall and spring semester.

Semester credits: 1-4.

CHEM 299 Independent Study

Faculty: Chemistry Faculty

Content: Laboratory research or individual study topics arranged in consultation with a faculty supervisor. May be repeated for credit.

Prerequisites: None.

Restrictions: Sophomore standing and consent required.

Usually offered: Annually, fall and spring semester.

Semester credits: 1-4.

CHEM 305 Aquatic Chemistry

Faculty: Balko

Content: Principles of chemistry applied to processes governing the composition of natural waters. Focus on the solubility equilibria that control the concentration of inorganic compounds (e.g. carbonate and silicates), kinetics of mineral growth and dissolution, the role of acid-base reactions and redox equilibria.

Prerequisites: CHEM 210. CHEM 220 (may be taken concurrently).

Restrictions: Sophomore standing required.

Usually offered: Every third year, fall semester.

Semester credits: 2.

CHEM 310 Physical Chemistry: Thermodynamics and Kinetics

Faculty: Balko, de Paula, Kuo, Loening

Content: Fundamental concepts of classical physical chemistry. Thermodynamics first, second, and third laws; phase equilibria; chemical equilibria; kinetics theory and practice; reaction rates.

Prerequisites: CHEM 120. PHYS 142 or PHYS 152. MATH 132.

Restrictions: Sophomore standing required.

Usually offered: Annually, spring semester.

Semester credits: 4.

CHEM 320 Physical Chemistry: Statistical Mechanics and Quantum Chemistry

Faculty: Balko, de Paula, Loening

Content: Statistical mechanics; quantum mechanics; quantum theory; molecular orbital theory; atomic and molecular spectroscopy; magnetic resonance spectroscopy; molecular modeling.

Prerequisites: CHEM 120. PHYS 142 or PHYS 152. MATH 132.

Restrictions: Sophomore standing required.

Usually offered: Annually, fall semester.

Semester credits: 4.

CHEM 330 Structural Biochemistry

Faculty: Lochner, Loening

Content: The structure-function relationship of biological molecules.

Principles governing protein folding and methods used to assess protein structure; case studies illustrating how protein structure dictates function; DNA structure and the chemistry of protein-DNA interactions; membrane biochemistry and the dynamics of membrane organization; role of the membrane in facilitating transport, intracellular communication, and mediating the transmission of nerve signals.

Prerequisites: CHEM 220.

Restrictions: Sophomore standing required.

Usually offered: Annually, fall semester.

Semester credits: 4.

CHEM 335 Metabolic Biochemistry

Faculty: Lochner

Content: Systematic assessment of how the cell derives metabolic energy and uses the energy to drive biosynthetic reactions. Principles of thermodynamics as applied to biological transformations of energy; allosterism and enzyme reaction mechanism; metabolic regulation in guiding the flow of cellular metabolites; defects in metabolic pathways; the biochemical basis of disease.

Prerequisites: CHEM 220.

Restrictions: Sophomore standing required.

Usually offered: Annually, spring semester.

Semester credits: 4.

CHEM 336 Biochemistry Laboratory

Faculty: Lochner, Loening

Content: Contemporary biochemical techniques introduced in a project-based format. Protein production using recombinant DNA techniques; protein purification using tools such as affinity and liquid chromatography; characterization of proteins using spectroscopy and electrophoresis; functional characterization of purified proteins.

Prerequisites: CHEM 330 and CHEM 335. (CHEM 335 may be taken concurrently.)

Restrictions: Sophomore standing required.

Usually offered: Annually, spring semester.

Semester credits: 2.

CHEM 365 Physical Chemistry Laboratory

Faculty: Balko, de Paula, Loening

Content: Laboratory course to demonstrate the principles of physical chemistry and to develop research aptitude in chemistry. Investigation of thermochemistry, phase equilibria, kinetics, spectroscopy, and solid-state studies using techniques such as calorimetry, UV-visible, IR, NMR, mass spectroscopies, and diffraction. Attendance at departmental seminars required. Lecture, laboratory, oral presentations.

Prerequisites: CHEM 310 or CHEM 320 (may be taken concurrently).

Restrictions: Sophomore standing required.

Usually offered: Annually, spring semester.

Semester credits: 3.

CHEM 366 Inorganic Chemistry Laboratory

Faculty: Bentley, Kuo

Content: Introduction to classical and modern techniques for synthesizing inorganic compounds of representative and transition metal elements and the extensive use of IR, NMR, mass, and UV-visible spectroscopies and other physical measurements to characterize products. Syntheses and characterization of inorganic and organic materials/polymers are included. Attendance at departmental seminars required. Lecture, laboratory, oral presentations.

Prerequisites: CHEM 220.

Restrictions: Sophomore standing required.

Usually offered: Annually, fall semester.

Semester credits: 3.

CHEM 405 Chemistry Seminar

Faculty: Chemistry Faculty

Content: Preparation and delivery of a seminar with accompanying abstract and bibliography. The seminar focus is either on a relevant topic in the chemical literature or, for students pursuing senior and honors research, on the thesis proposal.

Prerequisites: None.

Restrictions: Senior standing required.

Usually offered: Annually, fall and spring semester.

Semester credits: 1.

CHEM 415 Nanomaterials Chemistry

Faculty: Bentley

Content: Chemical preparation and characterization of materials featuring at least one physical dimension constrained to 100 nm or less. Emphasis on applications chosen from energy, medicine, catalysis, and information storage. Emerging public understanding of nanotechnology and research into environmental health and safety impacts.

Prerequisites: CHEM 210. CHEM 220 (may be taken concurrently—see registrar for assistance with registration).

Restrictions: Sophomore standing required.

Usually offered: Every third year, spring semester.

Semester credits: 2.

CHEM 420 Advanced Inorganic Chemistry

Faculty: Bentley

Content: Modern concepts of inorganic and transition-metal chemistry with emphasis on bonding, structure, thermodynamics, kinetics and mechanisms, and periodic and family relationships. Atomic structure, theories of bonding, symmetry, molecular shapes (point groups), crystal geometries, acid-base theories, survey of familiar elements, boron hydrides, solid-state materials, nomenclature, crystal field theory, molecular orbital theory, isomerism, geometries, magnetic and optical phenomena, spectra, synthetic methods, organometallic compounds, cage structures, clusters, lanthanides, actinides.

Prerequisites: CHEM 320.

Restrictions: Sophomore standing required.

Usually offered: Annually, spring semester.

Semester credits: 4.

CHEM 421 Neurochemistry

Faculty: Lochner

Content: Neurochemistry of synaptic transmission and an introduction to chemical approaches used to unravel the mechanistic basis of neuronal communication. Neurotransmitters, neuromodulatory proteins, and the mechanistic workings of ion channels and neuroreceptors. Neuronal processing of sensory information and intracellular signal transduction pathways. Neurochemical mechanisms that underlie memory, learning, and behavior. Behavioral sequelae that result from neurochemical abnormalities.

Prerequisites: CHEM 330 (may be taken concurrently).

Restrictions: Sophomore standing required.

Usually offered: Every third year, fall semester.

Semester credits: 2.

CHEM 443 Medicinal Organic Chemistry

Faculty: Kuo

Content: Bioorganic chemistry for selected medicinal compounds. Biophysical and chemical concepts of drug-receptor interactions and drug action. Biochemical basis for drug action elucidated in the context of fundamental organic mechanisms.

Prerequisites: CHEM 220.

Restrictions: Sophomore standing required.

Usually offered: Every third year, fall and spring semester.

Semester credits: 2.

CHEM 462 Advanced Organic Synthesis

Faculty: Jones

Content: Chemical synthesis using the systematic "synthon" approach to design retrosynthetic pathways for complex molecules. Approaches for advanced stereochemical control. Successful synthesis routes in the primary literature examined and the experimental section of these articles interpreted to successfully bridge the gap from journal to bench.

Prerequisites: CHEM 220.

Restrictions: Sophomore standing required.

Usually offered: Every third year, spring semester.

Semester credits: 2.

CHEM 464 Biomolecular NMR Spectroscopy

Faculty: Loening

Content: Advanced topics in nuclear magnetic resonance spectroscopy, with an emphasis on structural biology applications. Fundamental NMR theory, multidimensional methods, heteronuclear experiments, correlation spectroscopy, the nuclear Overhauser effect, chemical exchange, protein structure determination, protein dynamics.

Prerequisites: CHEM 220. CHEM 320 and/or CHEM 330 are recommended.

Restrictions: Sophomore standing required.

Usually offered: Every third year, fall and spring semester.

Semester credits: 2.

CHEM 480 Senior Research

Faculty: Chemistry Faculty

Content: Experimental and/or theoretical research on an advanced topic of current significance in chemistry. Students present their thesis proposals in an early fall seminar and detail results of their investigations in a thesis in the spring. Taken for 4 semester credits each semester of the senior year. A deferred grade will be issued for the first semester of the yearlong series. When the full sequence is completed, the given grade applies to both semesters.

Prerequisites: None.

Restrictions: Senior standing and consent of instructor required.

Usually offered: Annually, fall and spring semester.

Semester credits: 4.

CHEM 499 Independent Research

Faculty: Chemistry Faculty

Content: Participation in a faculty-supervised research project. Details, including academic credit, determined by the student in consultation with faculty supervisor. May be repeated for credit.

Prerequisites: Research experience.

Restrictions: Junior standing, consent of department chair, and consent of supervising faculty member required.

Usually offered: Annually, fall and spring semester.

Semester credits: 1-4.