Chemistry

Chairs: Nikolaus Loening
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 (http://docs.lclark.edu/catalog/archive/2012-2013/undergraduate/biochemmolebio/).

Resources for Nonmajors

CHEM 100 Perspectives in Environmental Chemistry, CHEM 105 Perspectives in Nutrition, and CHEM 114 The Origins of Life in the Universe 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 one lecture-demonstration theatre; a well-equipped biochemistry laboratory; modern scientific instrumentation (FT-NMR, FT-IR, GC-MS, HPLC, UV-VIS, AA, 12 molecular modeling workstations); a data analysis room; an organic chemistry instrumentation room; special laboratories for general chemistry, organic chemistry, and advanced analytical, physical, and inorganic chemistry; and student-faculty research laboratories.

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 degree. 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 an upper-division elective selected from the following:
  - CHEM 305 Aquatic Chemistry
  - CHEM 330 Structural Biochemistry
  - CHEM 335 Metabolic Biochemistry
  - CHEM 355 Experimental Methods in the Physical Sciences
  - CHEM 415 Nanomaterials Chemistry
  - CHEM 421 Neurochemistry
  - CHEM 443 Medicinal Organic Chemistry
CHEM 460  Topics in Modern Physical Organic Chemistry  
CHEM 464  Biomolecular NMR Spectroscopy

Mathematics  
• MATH 131 Calculus I  
• MATH 132 Calculus II

Physics  
• One of the following sequences:  
  PHYS 141  Introductory General Physics I  
  PHYS 142  Introductory General Physics II
  or  
  PHYS 151  Physics I: Motion  
  PHYS 152  Physics II: Waves and Matter  
  PHYS 251  Physics III: Electromagnetism

For an American Chemical Society–certified major, in addition to the above requirements, the student must also complete the following:  
CHEM 330 Structural Biochemistry or CHEM 335 Metabolic Biochemistry  
CHEM 355 Experimental Methods in the Physical Sciences  
Four additional semester credits at the 300 or 400 level (higher than CHEM 310 Physical Chemistry: Thermodynamics and Kinetics)

Students may also be required to take CHEM 299 Independent Study, CHEM 480 Senior Research, CHEM 490 Chemistry Honors Research, or CHEM 499 Independent Research so that they have a total of 500 laboratory contact hours. MATH 225 Linear Algebra, MATH 233 Calculus III, and MATH 235 Differential Equations are recommended, with preference given to MATH 225 Linear Algebra and MATH 235 Differential Equations.

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 to meet minor requirements.

Honors and Senior Research  
Students are especially encouraged to do senior-level thesis research. Students who have distinguished themselves academically through the junior year (GPA of 3.500 or higher in chemistry and overall) are invited to participate in the honors program. Students who complete the program are, with faculty approval, awarded honors in chemistry on graduation. 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 faculty.

Faculty  
CHEM 100 Perspectives in Environmental Chemistry  
Faculty: Balko, 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: CS 102, MATH 055, or equivalent.  
Usually offered: Annually, spring semester.  
Semester credits: 4.

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 and spring semester.  
Semester credits: 4.

CHEM 110 General Chemistry I  
Faculty: Balko, Bentley, 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: CS 102, MATH 055, 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: CS 102, MATH 055, or equivalent.  
Usually offered: Alternate Years, spring semester.  
Semester credits: 4.

CHEM 120 General Chemistry II  
Faculty: Balko, Bentley, Kuo, Loening, Chemistry Faculty.  
Content: Continuation of General Chemistry I. Chemical equilibrium, kinetics, thermodynamics, electrochemistry, descriptive inorganic chemistry, coordination chemistry, nuclear 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: Duncan, 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 alkydes (acidity, addition reactions); introduction to organometallic compounds. Lecture, discussion, laboratory.  
Prerequisites: CHEM 120.  
Restrictions: Sophomore standing required, unless section number is preceded by an "F."  
Usually offered: Annually, fall semester.  
Semester credits: 5.

CHEM 220 Organic Chemistry II  
Faculty: Duncan, 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, aldoketones, 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 (diazoation, synthesis); chemistry of amines, amino acids, peptides, proteins, DNA; other topics. Lecture, discussion, laboratory.  
Prerequisites: CHEM 210.  
Restrictions: Sophomore standing required, unless section number is preceded by an "F."  
Usually offered: Annually, spring semester.  
Semester credits: 5.
**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—contact the registrar for assistance in registration) or consent of instructor.  
Restrictions: Sophomore standing required.  
Usually offered: Alternate Years, fall semester.  
Semester credits: 2.

**CHEM 310 Physical Chemistry: Thermodynamics and Kinetics**  
Faculty: Balko, 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, 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, Chemistry Faculty.  
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 purification using both recombinant DNA techniques and classical tools such as affinity chromatography; functional characterization of the purified protein. Cellular metabolic responses and transmembrane signaling reactions studied using HPLC, radioisotope studies, enzyme analyses.  
Prerequisites: CHEM 330 or CHEM 335 (may be taken concurrently; contact the registrar for assistance with registration).  
Restrictions: Sophomore standing required.  
Usually offered: Annually, spring semester.  
Semester credits: 4.
CHEM 355 Experimental Methods in the Physical Sciences
Faculty: Loening, Tufte, Chemistry Faculty.
Content: Experimental methods and instrumentation in the physical sciences. Design experiments, construct instrumentation, make measurements, and analyze and interpret data in order to reach meaningful conclusions. Discussion and use of modern experimental techniques, including analog and digital electronics, many types of sensors, computerized data acquisition, spectroscopy (atomic, fluorescence, and infrared), mass spectrometry, and chromatography. Final student-designed project provides opportunities for interdisciplinary investigations. This course is taught in conjunction with PHYS 201. Credit may not be earned for both CHEM 355 and PHYS 201.
Prerequisites: CHEM 120. PHYS 141 or PHYS 151; or consent of instructor.
Corequisites: CHEM 220. PHYS 142 or PHYS 152; or consent of instructor.
Restrictions: Sophomore standing required.
Usually offered: Annually, spring semester.
Semester credits: 4.

CHEM 365 Physical Chemistry Laboratory
Faculty: Balko, 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 spectrocopies, 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: 2.

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/polymeres 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: Alternate Years, 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 or consent of instructor.
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 neuromodulators. 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 220. BIO 200 recommended.
Restrictions: Sophomore standing required.
Usually offered: Alternate Years, 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.
Semester credits: 2.

CHEM 460 Topics in Modern Physical Organic Chemistry
Faculty: Duncan.
Content: Modern approach to the study of the interrelationships between structure and reactivity in organic molecules: advanced stereochemistry; energy surfaces and kinetics; advanced electronic structure theory, including computational methods; thermal pericyclic reactions. Subject to interests of students and instructor, substitute physical organic topics might include photochemistry, linear free-energy relationships, catalysis, electronic organic materials, molecular recognition, supramolecular chemistry.
Prerequisites: CHEM 220.
Corequisites: CHEM 320 or consent of instructor.
Restrictions: Sophomore standing required.
Usually offered: Alternate Years, fall 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: Alternate Years, 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.
Prerequisites: None.
Restrictions: Senior standing and consent of instructor required.
Usually offered: Annually, fall and spring semester.
Semester credits: 4.

CHEM 490 Chemistry Honors 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 theses in the spring. Taken for 4 semester credits each semester of the senior year.
Prerequisites: None.
Restrictions: By invitation. Senior standing 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.