Chemistry

Chair

- Renee S. Cole

Undergraduate major: chemistry (BA, BS)

Undergraduate minor: chemistry

Graduate degrees: MS in chemistry; PhD in chemistry

Graduate certificate: radiochemistry

Faculty: https://chem.uiowa.edu/people

Website: https://chem.uiowa.edu/

The Department of Chemistry is committed to providing its undergraduate students with the skills needed to comprehend and confront the scientific challenges of the new century. The department's strong and vibrant undergraduate chemistry program is an environment where students can develop and ultimately find success in their chosen career paths.

The graduate programs in chemistry train scholars to lead efforts in chemistry research and teaching. One of the primary goals is to train students to become independent scientists. The department offers coursework to provide the foundational knowledge that enhances student efforts in the laboratory.

Student Organizations

A number of organizations are open to undergraduate students for support and enrichment.

Students may join the University of Iowa undergraduate student chapter of the American Chemical Society (ACS). Chapter activities include dinner meetings with guest speakers, field trips to local industries, participation in local and national meetings of the ACS, and participation in chemistry outreach programs. Students in the ACS student chapter develop valuable leadership, organization, and speaking skills during their college experience and throughout their careers.

The department has a chapter of Alpha Chi Sigma, a coed chemistry fraternity. The Alpha Theta Chapter is open to students in chemistry, biochemistry, chemical engineering, and related fields. Alpha Chi Sigma sponsors many social and professional events throughout the year.

The department endorses the National Organization for the Professional Advancement of Black Chemists and Chemical Engineers (NOBCChE), which is committed to discovery, transmittal, and application of knowledge in science and engineering and to increasing the participation of underrepresented populations in these fields. NOBCChE sponsors diverse programs designed to foster professional development and to encourage students to pursue careers in science and technical fields.

The department also supports the activities of Women in STEM Ambassadors (WiSA), whose aim is to increase women's participation and advancement as students, faculty members, and professional staff; promote a supportive study and work environment for women; integrate women's ideas, strengths, and approaches into research, teaching, and service; and inform the public of educational and career opportunities for women in scientific and technical fields. WiSA sponsors a living learning community in a university residence hall for first-year female students majoring in science or engineering, the Student-to-Student Support in Science mentoring program, a service learning program, and the WiSA Discourse and Dining series.

Programs

Undergraduate Programs of Study

Majors

- Major in Chemistry (Bachelor of Arts)
- Major in Chemistry (Bachelor of Science)

Minor

- Minor in Chemistry

Graduate Programs of Study

Majors

- Master of Science in Chemistry
- Doctor of Philosophy in Chemistry

Certificate

- Certificate in Radiochemistry

Facilities

The Department of Chemistry's main office, support facilities, and faculty offices are located in the Chemistry Building, as is laboratory and classroom space dedicated to teaching and research activities. Several faculty members have offices and laboratories in the Iowa Advanced Technology Laboratories across the street from the Chemistry Building. Extensive resources are readily accessible such as nuclear magnetic resonance (NMR), mass spectrometry, and X-ray analysis facilities, advanced computational resources, and complete machine, electronics, and glass shops. See the Department of Chemistry website for information about facilities and advanced instrumentation available for instruction and research.

The Chemistry Center serves all students who take chemistry courses as well as the department's instructors. The center offers assistance with registration, returns examinations and homework assignments, schedules alternative exams, and provides information about all lower-level chemistry courses. Information about student organizations and departmental scholarships and awards also is available at the Chemistry Center.

Courses

Chemistry Courses

Students planning to take more than one year of chemistry should take CHEM:1110 Principles of Chemistry I and CHEM:1120 Principles of Chemistry II.

Students who require only one year of chemistry with no laboratory component may take CHEM:1070 General Chemistry I and CHEM:1080 General Chemistry II.

Students who have not had high school chemistry or do not have strong math and/or chemistry preparation should consider taking CHEM:1070 General Chemistry I before CHEM:1110 Principles of Chemistry I; academic advisors and

the Chemistry Diagnostic Test can help students determine which of these courses to take first.

CHEM:0500 Review of Chemistry Fundamentals 0 s.h.
Self-paced course to prepare for and improve success in CHEM:1110; students acquire an appropriate mathematics background and a sound understanding of some fundamentals of chemistry; use of ALEKS to test individual chemistry knowledge and then computerized adaptive learning software to fill gaps in knowledge.

CHEM:1000 First-Year Seminar 1-2 s.h.
Small discussion class taught by a faculty member; topics chosen by instructor; may include outside activities (e.g., films, lectures, performances, readings, visits to research facilities). Requirements: first- or second-semester standing.

CHEM:1050 Chemistry of Our World 3 s.h.
Nonmathematical exploration of selected areas of technology; basic science background, current technological applications, implications for society; for non-science majors. GE: Sustainability. GE: Natural Sciences without Lab.

CHEM:1060 Technology and Society Laboratory 1 s.h.
Laboratory for CHEM:1050; demonstrations, student experiments. GE: Natural Sciences Lab only.

CHEM:1070 General Chemistry I 3 s.h.
Atomic structure, chemical bonds, mole relations, stoichiometry, states of matter, acids and bases, reaction rates, electrochemistry, nuclear chemistry. GE: Natural Sciences without Lab.

CHEM:1080 General Chemistry II 3 s.h.
Organic chemistry and biochemistry. GE: Natural Sciences without Lab.

CHEM:1090 Supplemental Chemistry Lab 1 s.h.
Lab techniques, elementary synthesis, measurement, analysis, case-study lectures and experiments; safety glasses, appropriate dress, compliance with laboratory safety protocols required.

CHEM:1100 Chemistry in Industry and the Economy 3 s.h.
Atomic structure, chemical bonding, acid and bases, polymers, pharmaceutics, DNA, proteins, and basic economics. GE: Natural Sciences without Lab.

CHEM:1110 Principles of Chemistry I 4 s.h.
Chemical bonding and chemical reactions; atomic and molecular structure, chemical equations, stoichiometry, gases, liquids, thermodynamics of phase changes, solutions, equilibrium, acids, bases, pH, elementary organic chemistry; the solid state, including modern materials; lecture, discussion, laboratory. Prerequisites: ALEKS score of 55 or higher or MPT Level 3 score of 9 or higher or MATH:1005 with a minimum grade of C- or MATH:1010 with a minimum grade of C- or MATH:1020 with a minimum grade of C- or MATH:1340 with a minimum grade of C- or MATH:1440 with a minimum grade of C- or MATH:1460 with a minimum grade of C- or MATH:1550 with a minimum grade of C- or MATH:1850 with a minimum grade of C-. Recommendations: Chemistry Diagnostic Test score of 16. GE: Natural Sciences with Lab.

CHEM:1120 Principles of Chemistry II 4 s.h.
Continuation of CHEM:1110; colligative properties of solutions, chemical thermodynamics, electrochemistry, chemical kinetics, chemical bonding, aspects of industrial chemistry, nuclear chemistry; lecture, discussion, laboratory. Prerequisites: CHEM:1110 with a minimum grade of C-. GE: Natural Sciences with Lab.

CHEM:1160 Principles of Chemistry Lab 2 s.h.
Laboratory techniques. GE: Natural Sciences Lab only.

CHEM:2021 Fundamentals of Chemical Measurements 3 s.h.
Introduction to experimental and data analysis techniques used in performing quantitative chemical measurements; topics include titrations, spectrophotometry, potentiometry, chromatography, and statistical techniques for use in data processing and interpretation; laboratory. Prerequisites: CHEM:1120 with a minimum grade of C-. Requirements: chemistry major.

CHEM:2210 Organic Chemistry I 3 s.h.
Carbon-containing compounds; structure, stereochemistry, physical properties, reactivity, reaction mechanisms, synthesis; emphasis on alkanes, alkenes, alkynes, ethers, alcohols, and alkyl halides. Prerequisites: CHEM:1120 with a minimum grade of C-.

CHEM:2220 Organic Chemistry II 3 s.h.
Continuation of CHEM:2210; use of spectroscopic techniques to determine chemical structures; chemistry of carbonyl compounds, amines, aromatics, amino acids, carbohydrates, nucleosides. Prerequisites: CHEM:2210 with a minimum grade of C- or CHEM:2230 with a minimum grade of C-.

CHEM:2230 Organic Chemistry I for Majors 3 s.h.
Carbon-containing compounds; structure, stereochemistry, physical properties, reactivity, reaction mechanisms, synthesis; emphasis on alkanes, alkenes, alkynes, alcohols, alkyl halides, aromatics. Prerequisites: CHEM:1120 with a minimum grade of C-. Recommendations: chemistry, biochemistry, or chemical engineering major.

CHEM:2240 Organic Chemistry II for Majors 3 s.h.
Continuation of CHEM:2230; use of spectroscopic techniques to determine chemical structures; chemistry of carbonyl compounds, amines, ethers, amino acids, carbohydrates, and nucleosides. Prerequisites: CHEM:2210 with a minimum grade of C- or CHEM:2230 with a minimum grade of C-. Recommendations: chemistry, biochemistry, or chemical engineering major.

CHEM:2410 Organic Chemistry Laboratory 3 s.h.
Preparation, purification, identification, analysis of chemical compounds, principally organic compounds. Prerequisites: CHEM:1120 with a minimum grade of C- and (CHEM:2210 with a minimum grade of C- or CHEM:2230 with a minimum grade of C-). Corequisites: CHEM:2220 or CHEM:2240.

CHEM:2420 Organic Chemistry Laboratory for Majors 3 s.h.
Preparation, purification, identification, analysis of chemical compounds, principally organic compounds. Prerequisites: CHEM:1120 with a minimum grade of C- and (CHEM:2210 with a minimum grade of C- or CHEM:2230 with a minimum grade of C-). Corequisites: CHEM:2220 or CHEM:2240. Recommendations: chemistry, biochemistry, or chemical engineering major.

CHEM:3110 Equilibria and Electrochemistry 3 s.h.
Modern theory and practice; emphasis on chemical equilibria (acid-base chemistry, solubility, complexation) and electroanalytical chemistry (potentiometry, voltammetry, coulometry). Prerequisites: CHEM:1120 with a minimum grade of C-.

CHEM:3120 Spectroscopy and Separations 3 s.h.
Modern theory and practice; emphasis on atomic and molecular spectroscopy, mass spectrometry, chemical separations. Prerequisites: CHEM:1120 with a minimum grade of C-.

CHEM:3250 Inorganic Chemistry 3 s.h.
Modern principles; emphasis on descriptive chemistry of the main group and transition elements, ionic and covalent chemical bonding theories, symmetry, inorganic stereochemistry. Prerequisites: CHEM:2210 with a minimum grade of C- or CHEM:2230 with a minimum grade of C-. Corequisites: CHEM:2220 or CHEM:2240.

CHEM:3430 Analytical Measurements 3 s.h.
Modern theory and practice of laboratory methods; emphasis on experimental techniques and data analysis in spectroscopy, chromatography, electrochemistry. Prerequisites: CHEM:2021 with a minimum grade of C- and (CHEM:3110 with a minimum grade of C- or CHEM:3120 with a minimum grade of C-). Recommendations: (PHYS:1511 or PHYS:1611) and (PHYS:1512 or PHYS:1612).

CHEM:3440 Physical Measurements 3 s.h.
Laboratory experience using advanced instrumental and computational methods to generate and analyze data relevant to modern physical chemistry. Prerequisites: CHEM:2021 with a minimum grade of C- and (CHEM:4431 with a minimum grade of C- or CHEM:4432 with a minimum grade of C-).

CHEM:3530 Inorganic Chemistry Laboratory 3 s.h.
Preparation and characterization of a variety of inorganic, organometallic, and coordination compounds of the main group and transition elements; emphasis on synthetic techniques, methods for characterization of inorganic species. Prerequisites: CHEM:3250 with a minimum grade of C- and (CHEM:2410 with a minimum grade of C- or CHEM:2420 with a minimum grade of C-) and CHEM:2021 with a minimum grade of C-.

CHEM:3994 Undergraduate Research 1-4 s.h.

CHEM:4000 Scientists and Writers 1 s.h.
Science communication and collaborative skills that are highly sought after by employers in STEM firms including pharmaceutical firms, biotech start-ups, and many others; these same skills essential for reporting on, writing about, or translating science in any area; studio-style format. Same as JMC:4000, WRIT:4002.

CHEM:4270 Advanced Inorganic Chemistry 3 s.h.
Modern principles, including crystal field/ligand field/molecular orbital theory, inorganic reaction mechanisms, coordination chemistry, bioinorganic chemistry, main group and transition metal organometallic chemistry, solid-state inorganic chemistry. Prerequisites: CHEM:3250 with a minimum grade of C-.

CHEM:4372 Advanced Organic Chemistry 3 s.h.
Basic concepts from perspectives of structure, mechanism, synthesis, stereochemistry. Prerequisites: CHEM:2220 with a minimum grade of C- or CHEM:2240 with a minimum grade of C-.

CHEM:4430 Principles of Physical Chemistry 3 s.h.
Kinetics, transport properties, elementary thermodynamics, and selected topics in quantum mechanics and spectroscopy; emphasis on application of chemistry to areas of science including health and biosciences, environmental sciences, and related areas. Prerequisites: CHEM:1120 with a minimum grade of C- and (MATH:1460 with a minimum grade of C- or MATH:1550 with a minimum grade of C- or MATH:1850 with a minimum grade of C-). Recommendations: (PHYS:1511 or PHYS:1611) and (PHYS:1512 or PHYS:1612).

CHEM:4431 Chemical Thermodynamics 3 s.h.
Chemical thermodynamics and its application to chemical equilibrium, phase changes and chemical equilibria; ideal and real gases; kinetic theory; surface absorption and electrochemistry; thermodynamics. Prerequisites: CHEM:1120 with a minimum grade of C- and (MATH:1560 with a minimum grade of C- or MATH:1860 with a minimum grade of C-).

CHEM:4432 Quantum Mechanics and Chemical Kinetics 3 s.h.
Quantum mechanics and its application to atomic and molecular structure; determination of structure and bonding by various spectroscopic methods; chemical kinetics. Prerequisites: CHEM:1120 with a minimum grade of C- and (MATH:1560 with a minimum grade of C- or MATH:1860 with a minimum grade of C-). Recommendations: PHYS:1512 or PHYS:1612.

CHEM:4450 Synthesis and Measurement 3 s.h.
Laboratory investigations integrating synthesis and measurement techniques from inorganic, analytical, and physical chemistry; emphasis on modern applications of chemistry in biology, medicine, environmental science, catalysis, and materials science. Prerequisites: (CHEM:4432 with a minimum grade of C- or CHEM:4430 with a minimum grade of C- or CHEM:4431 with a minimum grade of C-) and (CHEM:2420 with a minimum grade of C- or CHEM:2410 with a minimum grade of C-) and (CHEM:3120 with a minimum grade of C- or CHEM:3110 with a minimum grade of C-) and CHEM:3250 with a minimum grade of C- and CHEM:2021 with a minimum grade of C-.

CHEM:4480 Introduction to Molecular Modeling 3 s.h.
Theory and application of *ab initio* quantum mechanics, semiempirical molecular orbital theory, and molecular mechanics force fields to chemical research problems; underlying theory of these methods (with emphasis on *ab initio* theory) and their practical application to chemical problems; computational chemistry projects using modeling software. Prerequisites: CHEM:2220 with a minimum grade of C- or CHEM:2240 with a minimum grade of C-. Recommendations: CHEM:4432.

CHEM:4760 Radiochemistry: Energy, Medicine, and the Environment 3 s.h.
Fundamental theoretical concepts of radiochemistry and their application in energy, medicine, and environmental sectors. Prerequisites: CHEM:2210 with a minimum grade of C- or CHEM:2230 with a minimum grade of C-.

CHEM:4850 Upstream Biotechnology Processes 2 s.h.
Introduction to fermentation, fermenter preparation, cell growth and medium requirements, inoculation, sampling, process termination, separation of cells, fermentation case study, enzyme activity, and biocatalysis. Same as PHAR:4850.

CHEM:4873 Atmospheric and Environmental Chemistry 3 s.h.
Fundamental chemical processes of importance in the atmosphere, soil, and water, with emphasis on kinetics and photochemistry of homogeneous and heterogeneous reactions, atmospheric structure and dynamics, global geochemical cycling, chemistry-climate relationships, environmental remediation strategies; experimental methods in field and laboratory studies.

CHEM:5013 Science Writing in Chemistry 1 s.h.
How to providing clear, simple, and direct scientific documents; formulating good scientific questions; developing scientific context; process of writing, critiquing, and rewriting scientific documents; accepting constructive criticism; creating constructive criticism for others; student-created independent scientific proposal suitable as a funding application. Prerequisites: CHEM:5091 and CHEM:7270. Corequisites: CHEM:7999. Requirements: all comprehensive exams completed and passed.

CHEM:5090 Graduate Program Preparation 0 s.h.
Equips incoming graduate students with essential knowledge about resources in the Chemistry Department and other areas pertinent to their studies; offers a streamlined process for administering proctored proficiency exams, ensuring that students can demonstrate their competency in key subject areas; provides a solid foundation to navigate the academic journey effectively and maximize the potential for success in students' respective fields.

CHEM:5091 Graduate Chemistry Orientation 2-3 s.h.
Pedagogy, safety, and research issues relevant to advanced chemistry careers.

CHEM:5107 Electrochemistry 2-3 s.h.
Fundamental aspects, including mass transport and electron transfer, electrochemical methodology (e.g., voltammetry and potentiometry), determination of homogeneous and heterogeneous reaction mechanisms. Recommendations: CHEM:3110 and CHEM:3120.

CHEM:5108 Spectroscopy 3 s.h.
Principles of atomic and molecular absorption and emission spectroscopy in ultraviolet, visible, and infrared regions of the spectrum, including fluorescence, phosphorescence, Raman spectroscopy; applications to analytical problems, with emphasis on modern instrumentation and methodology. Recommendations: CHEM:3110 and CHEM:3120.

CHEM:5109 Separations 3 s.h.
Analytical separations; basic theory, practical applications, instrumentation, modern techniques (extractions, gas and liquid chromatography, capillary electrophoresis), and detection (mass spectrometry). Recommendations: CHEM:3110 and CHEM:3120.

CHEM:5114 Chemical Systems Modeling 3 s.h.
Basic processes and techniques; these methods applied to systems relevant to students' own research. Recommendations: CHEM:3110 or CHEM:3120.

CHEM:5115 Biophotonics 3 s.h.
Structure, dynamics of biomolecules and their optical spectroscopy; ultrasensitive fluorescence spectroscopy, vibrational spectroscopy, optical activity and circular dichroism, time-resolved spectroscopy. Recommendations: CHEM:3110 and CHEM:3120.

CHEM:5118 Nanomaterials 3 s.h.
Basic principles associated with nanoscience and nanotechnology; fabrication and synthesis, size dependent properties, characterization, applications of materials at nanometer length scales, recent technological breakthroughs in the field. Requirements: graduate standing or advanced undergraduate standing in engineering and science. Recommendations: knowledge of basic chemistry.

CHEM:5121 Nuclear Physics Concepts 1 s.h.
Introduction to fundamental concepts describing the behavior of unstable nuclei, including radioactive emissions, radionuclide generation, and interaction with the physical world; the production and modes of decay of radionuclides, the concepts of radioactive decay and equilibrium, and radiation's interactions with matter; and the occurrence and importance of natural and anthropogenic radionuclides relative to their use and importance to the environment and human health.

CHEM:5122 Radiochemistry Separation Concepts I 1 s.h.
Chemical and physical manipulation samples that enable the identification and measurement of radionuclides. These concepts focus strongly on practical inorganic and analytical chemistry techniques, including sample handling, sample dissolution/destruction, oxidation state manipulation, equilibrium reactions, and analyte preconcentration. Addresses the analytical implications of various sample types, including matrix and radionuclides interferences, and various techniques for addressing these issues.

CHEM:5123 Radiochemistry Separation Concepts II 1 s.h.
Chemical and physical manipulation samples that enable the identification and measurement of radionuclides. These concepts focus strongly on practical inorganic and analytical chemistry techniques, including sample handling, sample dissolution/destruction, oxidation state manipulation, equilibrium reactions, and analyte preconcentration. Addresses the analytical implications of various sample types, including matrix and radionuclides interferences, and various techniques for addressing these issues.

CHEM:5124 Radiochemistry Instrumental Analysis I 1 s.h.
Theory, operation, calibration, and maintenance of instrumentation used for the identification and measurement of radiation. Instrumentation covered includes gas-flow proportional counters, Geiger-Müller counters, ionization chambers, liquid scintillation counters, semiconductor detectors, and solid scintillation detectors. For each technology introduced, students learn the fundamental concepts of detection, operation, calibration, troubleshooting, maintenance, and sample measurement.

CHEM:5125 Radiochemistry Instrumental Analysis II 1 s.h.
Theory, operation, calibration, and maintenance of instrumentation used for the identification and measurement of radiation. Instrumentation includes gas-flow proportional counters, Geiger-Müller counters, ionization chambers, liquid scintillation counters, semiconductor detectors, and solid scintillation detectors. For each technology introduced, students learn the fundamental concepts of detection, operation, calibration, troubleshooting, maintenance, and sample measurement.

CHEM:5126 Radiochemistry Data Analysis and Statistics 1 s.h.
Introduction to mathematical concepts and calculations used in radiochemistry to calculate analytical results and assess data, including radioactivity calculations, counting statistics, detection limit decisions, and uncertainty estimations used in the generation of analytical results, and the optimization and evaluation of analytical systems to meet data and measurement quality objectives using the previously listed concepts.

CHEM:5127 Radiochemistry Quality Assurance 1 s.h.
Various components of quality assurance that govern radiochemical analysis, including the traceability of measurements, the standardization of measurement systems, the process of obtaining and maintaining laboratory accreditation, the various quality control procedures used to ensure defensible data, and the regulatory standards impacting radiochemical measurements; best practices for method 9 and instrument validation, and the statistical concepts and tests for evaluating radiochemical data.

CHEM:5128 Radiation Safety and Health Physics 1 s.h.
Radiation safety and health physics concepts used to both minimize human exposure to radiation and evaluate its potential effect, including processes for minimizing and evaluating exposure, radioactive materials handling and exposure, licensure considerations, and dosimetry. Discussion of the biological effects of radiation, including both acute and chronic exposure outcomes, and the regulatory limits meant to minimize these effects.

CHEM:5129 Radiochemistry Separation Laboratory 2 s.h.
Introduces students to the radiochemistry laboratory environment and covers commonly used radiochemical separation techniques; fundamental laboratory safety and techniques including exposure and contamination control, waste disposal, sample preparation and preservation, and standard preparation and verification; perform radiochemical separation methods for gross alpha radium, tritium, and uranium using a variety of techniques including co-precipitation, distillation, extraction chromatography, and ion exchange.

CHEM:5130 Radiochemistry Instrumental Analysis Laboratory 2 s.h.
Introduces students to radiation measurement instruments and data analysis software; set-up, calibration, maintenance, and use of alpha scintillation counters, gamma spectrophotometers, gas-flow proportional counters, and liquid scintillation counters; perform setup, calibration, and analysis with each of the listed instruments and their associated software packages.

CHEM:5150 Chemometrics 3 s.h.
Mathematical, statistical, and signal processing methods for analytical chemistry; hypothesis testing, experimental design, model building, optimization, digital filtering.

CHEM:5190 Seminar: Analytical Chemistry 0-1 s.h.

CHEM:5199 Special Topics in Analytical Chemistry arr.
Content varies.

CHEM:5203 Organometallic Chemistry 3 s.h.
Emphasis on organometallic compounds of transition metal elements. Corequisites: CHEM:4270.

CHEM:5204 Physical Methods in Inorganic Chemistry 3 s.h.
Application of physical methods to problems; recent developments; emphasis on magnetic resonance spectroscopy. Recommendations: CHEM:4270.

CHEM:5205 Bioinorganic Chemistry 2-3 s.h.
The role of metal ions in biology from an inorganic chemical perspective; emphasis on structure and mechanism for transition metal-containing metallo-enzymes.

CHEM:5206 Solid-State and Materials Chemistry 3 s.h.
Introduction to the chemical concepts of solid-state chemistry; focus on synthesis and characterization of various inorganic materials; structure/property relationships, real-world examples. Recommendations: CHEM:4270.

CHEM:5212 Mass Spectrometry 3 s.h.
Examination of mass spectrometry in terms of basic theory, instrumentation, qualitative and quantitative analysis, and its application to the environmental and biological sciences. Recommendations: CHEM:3110 or CHEM:3120.

CHEM:5290 Seminar: Inorganic and Chemical Education Research 0-1 s.h.

CHEM:5299 Special Topics in Inorganic Chemistry 1-3 s.h.
Recommendations: CHEM:4270.

CHEM:5321 Spectroscopic Methods in Organic Chemistry 3-4 s.h.
Methods and techniques of structure determination for organic compounds.

CHEM:5326 Organic Reactions 3 s.h.
Survey of organic reactions used in contemporary organic synthesis; emphasis on C-C bond forming reactions, functional group interconversions, oxidations and reductions; mechanistic details of reaction types; innovations in catalytic and asymmetric organic reactions. Recommendations: CHEM:4372.

CHEM:5328 Mechanisms of Organic Reactions 3 s.h.
Application of basic mechanistic concepts.

CHEM:5329 Advanced Organic Synthesis 1-3 s.h.
Preparation of complex organic compounds. Recommendations: CHEM:4372.

CHEM:5390 Seminar: Organic Chemistry 0-1 s.h.

CHEM:5399 Organic Chemistry Special Topics 1,3 s.h.
Recommendations: CHEM:4372.

CHEM:5431 Statistical Thermodynamics I 3 s.h.
Fundamentals of classical thermodynamics and equilibria; ensembles; noninteracting systems; theory of phase transitions; Monte-Carlo methods; classical fluids; nonequilibrium systems. Recommendations: CHEM:4431.

CHEM:5433 Quantum and Computational Chemistry 3 s.h.
Fundamental principles of quantum chemistry; angular momentum; approximation methods; theory of atomic and molecular electronic structure; applications of computational quantum mechanics to chemical systems. Corequisites: CHEM:4432, if not taken as a prerequisite.

CHEM:5434 Molecular Spectroscopy 3 s.h.
Quantum mechanical models of atoms, molecules, and chemical oscillators; electrostatics and magnetism; electromagnetic waves; refractive index and polarization; matter waves; symmetry and orbitals; vibronic and spin-orbit coupling; electron correlation and exchange; selection rules. Recommendations: CHEM:5433.

CHEM:5435 Chemical Kinetics 3 s.h.
Potential energy surfaces, transition state theory, diffusion limited rates, linear free energy relationships, isotope effects, solvent effects, RRKM theory; connection between experiment and various theories in the gas and solution phases; emphasis on assignment of experimental error to derived quantities. Recommendations: CHEM:4432.

CHEM:5438 Surface Chemistry and Heterogeneous Processes **3 s.h.**
Fundamental and applied aspects of surface chemical processes; theories of molecular adsorption/desorption and surface complexation; kinetics; surface analysis and instrumentation; applications of surface chemistry in heterogeneous catalysis, heterogeneous environmental/atmospheric processes, and materials chemistry. Recommendations: CHEM:4431.

CHEM:5490 Seminar: Physical and Environmental Chemistry **0-1 s.h.**

CHEM:5499 Physical Chemistry Topics **1-3 s.h.**
Advanced topics relevant to modern physical chemistry. Recommendations: CHEM:4432 and MATH:1860.

CHEM:5599 Special Topics in Chemistry Education **3 s.h.**
Special topics related to chemistry education; topics vary.

CHEM:5875 Perspectives in Biotechnology **1 s.h.**
Topics related to careers in biotechnology with an emphasis on preparing graduate students for careers outside of academia; discussions led by a series of guest speakers from leading biotech industries; understanding the societal impact of basic research; participation in round-table discussions; and presentation of student research findings. Requirements: graduate standing and good academic standing in a participating department supported by the Predoctoral Training Program in Biotechnology. Same as BMB:5875, CBE:5875, CEE:5875, MICR:5875, PHAR:5875.

CHEM:5990 Chemistry Colloquium **0-1 s.h.**
Presentation and discussion of research by invited presenters.

CHEM:6990 Research Seminar **0-1 s.h.**
Presentation and discussion of thesis research for advanced degrees.

CHEM:7270 Ethics in Chemical Sciences **1 s.h.**
Scholarly integrity for being a responsible chemist on graduate-level research; introduction to infrastructure of scientific scholarship with emphasis on interacting with peers, funding agencies, industrial entities; responsible conduct in research in the context of creation of knowledge, dissemination of scientific findings, intellectual property, and conflict of interest; workshops to study cases in chemical research to illustrate the principles of scholarly integrity.

CHEM:7604 Ethics in Chemical Sciences for Postdocs **0 s.h.**
Introduction to infrastructure of scientific scholarship; emphasis on interacting with peers, funding agencies, industrial entities; scholarly integrity for being a responsible chemist on graduate-level research; responsible conduct in research in context of creation of knowledge, dissemination of scientific findings, intellectual property, conflict of interest; workshop cases in chemical research that illustrate principles of scholarly integrity.

CHEM:7999 Research in Chemistry **arr.**
Thesis work for advanced degrees.