Chemistry

Interim chair
• Daniel M. Quinn

Undergraduate major: chemistry (B.A., B.S.)
Undergraduate minor: chemistry
Graduate degrees: M.S. in chemistry; Ph.D. in chemistry
Faculty: http://www.chem.uiowa.edu/people
Web site: http://www.chem.uiowa.edu/

Undergraduate Programs of Study

• Major in chemistry (Bachelor of Arts, Bachelor of Science)
• Minor in chemistry

The undergraduate major in chemistry provides a strong foundation for success in graduate and professional study and for positions in academic or industrial chemistry.

Bachelor of Arts, Bachelor of Science

The Bachelor of Arts with a major in chemistry requires a minimum of 120 s.h., including 53-54 s.h. of work for the major (20 s.h. in foundation chemistry courses, 12 s.h. in advanced chemistry, and 21-22 s.h. in supporting course work). The Bachelor of Science with a major in chemistry requires a minimum of 120 s.h., including 69 s.h. of work for the major (20 s.h. in foundation chemistry courses, 27 s.h. in advanced chemistry, and 22 s.h. in supporting course work). Students must maintain a g.p.a. of at least 2.00 in all courses for the major and in all UI courses for the major. They also must complete the College of Liberal Arts and Sciences General Education Program.

The chemistry major for the Bachelor of Arts provides a more general education than the B.S. program offers and may be the degree of choice for students who are interested in earning licensure to teach in secondary schools (see "B.A. or B.S. with Teacher Licensure" below). Advanced courses in chemistry, biology, mathematics, physics, or other science disciplines are recommended as electives for B.A. students. Those who choose appropriate electives may meet entrance requirements for graduate or professional programs such as chemistry, biochemistry, medicine, or dentistry. Graduates also may pursue careers and education in business, law, and other areas.

The chemistry major for the Bachelor of Science is certified by the American Chemical Society (ACS) when a biochemistry course is included. An ACS-approved program offers a broad-based and rigorous chemistry education that provides students with intellectual, experimental, and communication skills to become effective scientific professionals. Current and projected demand for Bachelor of Science graduates in chemistry is excellent in research and in control and process-development work. The program also provides all the prerequisites for graduate work in chemistry or biochemistry and in other biomedical areas with a molecular focus.

Bachelor of Arts and Bachelor of Science students take the same chemistry foundation courses, but their requirements in other areas are different. B.A. students must earn at least 11 s.h. in advanced chemistry courses at the University of Iowa; B.S. students must earn at least 20 s.h. in advanced chemistry courses at the University. Mathematics and preferred physics requirements also differ for the two degrees, and B.S. students may count undergraduate research toward the science electives requirement.

Courses in the chemistry major have prerequisites, so they must be taken in the correct order. Advanced chemistry courses are built on the chemistry foundation courses. Most advanced courses are taught only once a year. Students should consult their academic advisors and plan their course schedules carefully. They should take CHEM:2021 Basic Measurements during the first semester of the second year.

Students may not use a course to fulfill more than one requirement.

The major in chemistry requires the following course work.

**CHEMISTRY FOUNDATION COURSES (B.A. AND B.S.)**

All students (Bachelor of Arts and Bachelor of Science) complete the following foundation courses.

All of these:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Credit Hours</th>
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<tbody>
<tr>
<td>CHEM:1110 &amp; CHEM:1120 Principles of Chemistry I-II</td>
<td>8 s.h.</td>
</tr>
<tr>
<td>CHEM:2021 Basic Measurements</td>
<td>3 s.h.</td>
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One of these sequences:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Credit Hours</th>
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<tbody>
<tr>
<td>CHEM:2230 &amp; CHEM:2240 Organic Chemistry I for Majors - Organic Chemistry II for Majors (preferred)</td>
<td>6 s.h.</td>
</tr>
<tr>
<td>CHEM:2210 &amp; CHEM:2220 Organic Chemistry I-II</td>
<td>6 s.h.</td>
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One of these:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Credit Hours</th>
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<tbody>
<tr>
<td>CHEM:2420 Organic Chemistry Laboratory for Majors (preferred)</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>CHEM:2410 Organic Chemistry Laboratory</td>
<td>3 s.h.</td>
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</table>

**ADVANCED CHEMISTRY (B.A.)**

Bachelor of Arts students complete one of these:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Credit Hours</th>
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</thead>
<tbody>
<tr>
<td>CHEM:3120 Analytical Chemistry II (preferred)</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>CHEM:3110 Analytical Chemistry I</td>
<td>3 s.h.</td>
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</tbody>
</table>

And all of these:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Credit Hours</th>
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<tbody>
<tr>
<td>CHEM:3250 Inorganic Chemistry</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>CHEM:4430 Principles of Physical Chemistry</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>CHEM:4450 Synthesis and Measurement</td>
<td>3 s.h.</td>
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</tbody>
</table>

**ADVANCED CHEMISTRY (B.S.)**

Bachelor of Science students complete all of these:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Credit Hours</th>
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<tbody>
<tr>
<td>CHEM:3110 &amp; CHEM:3120 Analytical Chemistry I-II</td>
<td>6 s.h.</td>
</tr>
<tr>
<td>CHEM:3250 Inorganic Chemistry</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>CHEM:3430 Analytical Measurements</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>CHEM:3440 Physical Measurements</td>
<td>3 s.h.</td>
</tr>
<tr>
<td>CHEM:3530 Inorganic Chemistry Laboratory</td>
<td>3 s.h.</td>
</tr>
</tbody>
</table>
CHEM:4270 Advanced Inorganic Chemistry 3 s.h.
CHEM:4431-CHEM:4432 Physical Chemistry I-II 6 s.h.

MATH:460 Calculus for the Biological Sciences (preferred) 4 s.h.
MATH:1550 Engineering Mathematics I: Single Variable Calculus 4 s.h.
MATH:1850 Calculus I 4 s.h.

And one of these:
MATH:1560 Engineering Mathematics II: Multivariable Calculus 4 s.h.
MATH:1860 Calculus II 4 s.h.
STAT:2010 Statistical Methods and Computing 3 s.h.
STAT:3510 Biostatistics (preferred) 3 s.h.

CHEM:3110 Analytical Chemistry I 3 s.h.
CHEM:3120 Analytical Chemistry II 3 s.h.
CHEM:3430 Analytical Measurements 3 s.h.
CHEM:3440 Physical Measurements 3 s.h.
CHEM:3530 Inorganic Chemistry Laboratory 3 s.h.
CHEM:4171 Advanced Analytical Chemistry 3 s.h.
CHEM:4270 Advanced Inorganic Chemistry 3 s.h.
CHEM:4372 Advanced Organic Chemistry 3 s.h.
CHEM:4431 Physical Chemistry I 3 s.h.
CHEM:4432 Physical Chemistry II 3 s.h.
CHEM:4480 Introduction to Molecular Modeling 3 s.h.
CHEM:4760 Radiochemistry: Energy, Medicine, and the Environment 3 s.h.
CHEM:4873 Atmospheric and Environmental Chemistry 3 s.h.
CHEM:4875 Introduction to Polymer Chemistry 2-3 s.h.
BIOC:3110 Biochemistry 3 s.h.

BIOC:3120 Biochemistry and Molecular Biology 3 s.h.

SCIENCE ELECTIVES AND RESEARCH (B.S.)
Bachelor of Science students complete a total of 6 s.h. chosen from these:
CHEM:3994 Undergraduate Research 1-4 s.h.
BIOC:3110 Biochemistry 3 s.h.
BIOC:3120 Biochemistry and Molecular Biology 3 s.h.

Advanced science elective courses

ACS CERTIFICATION REQUIREMENT (B.S.)
Bachelor of Science students who want an ACS certified degree complete one of these optional courses (also listed above under “Science Electives and Research (B.S.)”):
BIOC:3110 Biochemistry 3 s.h.
BIOC:3120 Biochemistry and Molecular Biology 3 s.h.

B.A. or B.S. with Teacher Licensure
Chemistry majors interested in earning licensure to teach in elementary and/or secondary schools must complete the College of Education's Teacher Education Program (TEP) in addition to the requirements for the major and all requirements for graduation. The TEP requires several College of Education courses and student teaching. Contact the Office of Education Services for details.

Students must satisfy all degree requirements and complete Teacher Education Program licensure before degree conferral.

Students who plan to use their work toward a minor in chemistry as academic background for earning teacher licensure should contact the Office of Education Services about requirements.

Students with a strong interest in science teaching may complete a major offered by the Science Education Program. Students choose one of five emphases—biology, chemistry, earth science, physics, and all-science—and earn a Bachelor of Science degree. They may apply for admission to the Teacher Education Program. See Science Education in the Catalog.

Joint B.A./M.A.T. with Science Education Subprogram
B.A. students majoring in chemistry who are interested in pursuing a graduate degree in teaching may apply to the joint Bachelor of Arts/Master of Arts in Teaching program offered by the College of Liberal Arts and Sciences and the College of Education. Designed for undergraduates majoring in biology, chemistry, environmental sciences, or physics, the joint program enables students to earn a B.A.
and an M.A.T. in five years by beginning to earn graduate credit during their fourth year of undergraduate study and by counting up to 18 s.h. of qualifying credit toward both degrees. For more information, see “Joint B.A./M.A.T. with Science Education Subprogram” in the Teaching and Learning (College of Education) section of the Catalog. Interested students should consult an advisor.

Four-Year Graduation Plan

The following checkpoints list the minimum requirements students must complete by certain semesters in order to stay on the University’s Four-Year Graduation Plan. (Courses in the major are those required to complete the major; they may be offered by departments other than the major department.)

Note: Courses in the chemistry major have prerequisites, so they must be taken in the correct order. Most advanced courses are taught only once a year. Students should consult their academic advisors and plan their course schedules carefully. They should take CHEM:2021 Basic Measurements during the first semester of the second year. Typical chemistry course schedules (B.A. and B.S.) and a regression list are available at Requirements for Major on the department's web site.

Bachelor of Arts

Before the third semester begins: math through MATH:1460 Calculus for the Biological Sciences or calculus I; CHEM:1110 Principles of Chemistry I and CHEM:1120 Principles of Chemistry II, or CHEM:1180 Chemical Science I and CHEM:1190 Chemical Science II and CHEM:1200 Chemical Science Laboratory, or equivalent course work

Before the fifth semester begins: basic measurements; organic chemistry I, II, and lab; and biostatistics or calculus II

Before the seventh semester begins: two more courses in the major; physics I and II; and at least 90 s.h. earned toward the degree

Before the eighth semester begins: principles of physical chemistry and one more course in the major

During the eighth semester: enrollment in all remaining course work in the major, all remaining General Education courses, and a sufficient number of semester hours to graduate

Bachelor of Science

Before the third semester begins: math through calculus I; CHEM:1110 Principles of Chemistry I and CHEM:1120 Principles of Chemistry II, or CHEM:1180 Chemical Science I and CHEM:1190 Chemical Science II and CHEM:1200 Chemical Science Laboratory, or equivalent course work

Before the fifth semester begins: basic measurements; organic chemistry I, II, and lab; three other courses in the major; calculus II; physics I and II

Before the seventh semester begins: six more courses in the major and at least 90 s.h. earned toward the degree

Before the eighth semester begins: three more courses in the major

During the eighth semester: enrollment in all remaining course work in the major, all remaining General Education courses, and a sufficient number of semester hours to graduate

Honors in the Major

Students majoring in chemistry have the opportunity to graduate with honors in the major. Departmental honors students must maintain a cumulative University of Iowa g.p.a. of at least 3.33. In addition, students must complete an undergraduate research project acceptable to their research advisor and must write an honors thesis based on their research. Students can register for CHEM:3994 Undergraduate Research or HONR:3994 Honors Research Practicum in order to earn credit for their research. They are encouraged, but not required, to present their research at local and regional meetings and to publish their results in professional journals.

In addition to honors in their majors, undergraduate students have a variety of opportunities for honors study and activities through membership in the University of Iowa Honors Program; visit Honors at Iowa to learn about the University's honors program.

Minor

The minor in chemistry requires a minimum of 15 s.h. in chemistry courses, including 12 s.h. in courses numbered 2210 or above taken in the Department of Chemistry at the University of Iowa. Students must maintain a cumulative g.p.a. of at least 2.00 in all courses for the minor and in all UI courses for the minor. Course work in the minor may not be taken pass/nonpass.

The following courses do not count toward the minor.

CHEM:3560 Advanced Methods in Chemical Research: Special Topics 1-3 s.h.
CHEM:3994 Undergraduate Research 1-4 s.h.
CHEM:4261 Selected Topics in Chemistry 1-3 s.h.

Resources, Activities

The department offers undergraduate students majoring in chemistry and other students interested in chemistry a number of opportunities to enrich their classroom studies.

Undergraduate Chemistry Center

The Chemistry Center serves all students who take chemistry courses as well as the department's professors and teaching assistants. The center maintains waiting lists and offers other 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.

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 industry; participation in local and national meetings of the ACS; and participation in chemistry outreach programs. Students in the ACS student chapter develop leadership, organization, and
speaking skills valuable during their college experience and throughout their careers.

The department has a chapter of Alpha Chi Sigma, a co-ed 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 Science and Engineering (WISE), 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. WISE sponsors a living-learning community in Stanley Hall (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 WISE Discourse and Dining series.

**Scholarships and Awards**

A number of awards and scholarships are available to chemistry majors, including the American Institute of Chemists Award, the Undergraduate Award in Analytical Chemistry, the Chemistry Alumni Awards (one each for a sophomore, a junior, and a senior), the Merck Index Award, and the Viksnins, Harris & Padys PLLP Award.

Chemistry majors also may apply for the Donald J. and Margaret Burton Scholarship, Ken Sando Scholarship, Shoemaker-Strickler Scholarship, E. David Cater Scholarship, and Russell K. Simms Scholarship.

**Graduate Programs of Study**

- Master of Science in chemistry
- Doctor of Philosophy in chemistry

**Master of Science**

The Master of Science in chemistry requires a minimum of 30 s.h. of graduate credit. The degree is offered with or without thesis. M.S. students must demonstrate minimal proficiency in biochemistry, analytical, inorganic, organic, and physical chemistry by passing specific examinations or by enrolling in suitable core courses. This requirement must be completed by the end of the second year of enrollment. A g.p.a. of at least 3.00 is required for admission to the master's examination.

**Doctor of Philosophy**

The Doctor of Philosophy in chemistry requires a minimum of 72 s.h. of graduate credit. A Ph.D. in chemistry includes minimal proficiency examinations, core courses as necessary, a minimum of 11 s.h. of advanced course work, and research.

Students who meet the course requirements with a cumulative g.p.a. of 3.00 or higher are admitted to the oral comprehensive examination upon presentation and preliminary approval of their written research proposal and research progress report; they must take the oral comprehensive examination no later than the end of their second year of enrollment.

Upon completing Ph.D. research, candidates prepare the dissertation. The final examination consists of an oral defense of the thesis, at which time the candidate presents at least one manuscript of the publishable portion of his or her thesis.

**Admission**

Applicants for graduate admission should have a bachelor's degree with a major in chemistry or a related field, preferably with a g.p.a. of 3.00 or higher. Most admitted graduate students receive financial support. For application information, contact the Department of Chemistry or visit its web site.

Applicants must meet the admission requirements of the Graduate College; see the Manual of Rules and Regulations of the Graduate College.

**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. See the Department of Chemistry web site for information about facilities and advanced instrumentation available for instruction and research.

**Courses**

**Lower-Level Undergraduate**

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 II; academic advisors and the Chemistry Diagnostic Test can help students determine which of these courses to take first.

**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 Technology and Society 3 s.h.
Nonmathematical exploration of selected areas of technology; basic science background, current technological applications, implications for society; for nonscience majors. Recommendations: closed to students who have taken college chemistry courses. GE: Natural Sciences without Lab.

CHEM:1060 Technology and Society Laboratory 1 s.h.
Laboratory for CHEM:1050; demonstrations, student experiments. Corequisites: CHEM:1050 if not taken as a prerequisite. Requirements: closed to students who have earned more than 3 s.h. in chemistry courses. 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. Requirements: elementary algebra. GE: Natural Sciences without Lab.

CHEM:1080 General Chemistry II 3 s.h.
Organic chemistry and biochemistry. Requirements: CHEM:1070 or high school chemistry. 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. Requirements: non-science major. 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. Requirements: MATH:1005 or ACT math subscore of 24 and ALEKS score above 65%. 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. Recommendations: CHEM:1110. GE: Natural Sciences with Lab.

CHEM:1160 Principles of Chemistry Lab 2 s.h.
Laboratory techniques. Requirements: grades of C or higher in CHEM:1180 and CHEM:1190. GE: Natural Sciences Lab only.

CHEM:1180 Chemical Science I 3 s.h.
GE: Natural Sciences without Lab.
Upper-Level Undergraduate and Graduate

CHEM:3110 Analytical Chemistry I 3 s.h.
Modern theory and practice; emphasis on chemical equilibria (acid-base chemistry, solubility, complexation) and instrumental and electroanalytical chemistry (potentiometry, voltammetry, coulometry). Recommendations: CHEM:1120, and MATH:1460 or MATH:1850, and PHYS:1511 or PHYS:1611.

CHEM:3120 Analytical Chemistry II 3 s.h.
Modern theory and practice; emphasis on atomic and molecular spectroscopy, mass spectrometry, chemical separations. Recommendations: CHEM:1120, and MATH:1460 or MATH:1850, and PHYS:1511 or PHYS:1611.

CHEM:3250 Inorganic Chemistry 2-3 s.h.
Modern principles; emphasis on descriptive chemistry of the main group and transition elements, ionic and covalent chemical bonding theories, symmetry, inorganic stereochemistry. Recommendations: CHEM:1120, and CHEM:2220 or CHEM:2240.

CHEM:3430 Analytical Measurements 3 s.h.

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. Requirements: chemistry major. Recommendations: CHEM:2021, and CHEM:4431 or CHEM:4432, and CHEM:4431 or CHEM:4432.

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:2410 or CHEM:2420) and CHEM:3250.

CHEM:3560 Advanced Methods in Chemical Research: Special Topics 1-3 s.h.
Introduction to advanced research methods.

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

CHEM:4171 Advanced Analytical Chemistry 3 s.h.

CHEM:4261 Selected Topics in Chemistry 1-3 s.h.
Prerequisites: CHEM:2210 or CHEM:2230.

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. Corequisites: CHEM:3530, if not taken as a prerequisite. Recommendations: CHEM:3250 and CHEM:4432.

CHEM:4372 Advanced Organic Chemistry 3 s.h.
Basic concepts from perspectives of structure, mechanism, synthesis, stereochemistry. Recommendations: CHEM:2220 or CHEM:2240.

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. Recommendations: CHEM:1120, and MATH:1460 or MATH:1850, and PHYS:1512 or PHYS:1612.

CHEM:4431 Physical Chemistry I 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. Recommendations: CHEM:1120, and MATH:1560 or MATH:1860, and PHYS:1512 or PHYS:1612.

CHEM:4432 Physical Chemistry II 3 s.h.
Quantum mechanics and its application to atomic and molecular structure; determination of structure and bonding by various spectroscopic methods; chemical kinetics. Recommendations: CHEM:1120, and MATH:1560 or MATH:1860, and 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. Recommendations: CHEM:2021, and CHEM:2410 or CHEM:2420, and CHEM:3110 or CHEM:3120, and CHEM:3250, and CHEM:4430 or CHEM:4431 or CHEM:4432.

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. Corequisites: CHEM:4432, if not taken as a prerequisite.

CHEM:4760 Radiochemistry: Energy, Medicine, and the Environment 3 s.h.
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. Corequisites: CHEM:4431 or CHEM:4432, if not taken as a prerequisite.

CHEM:4875 Introduction to Polymer Chemistry 2-3 s.h.

Graduate

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

CHEM:5092 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: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, CHEM:3120, and CHEM:4171.

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, CHEM:3120, and CHEM:4171.

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, CHEM:3120, and CHEM:4171.

CHEM:5110 Chemical Sensors 2 s.h.
Theory, practical limitations, analytical utility based on immobilized reagents with electrochemical, thermal, optical transduction mechanisms. Recommendations: CHEM:3110 and CHEM:3120, or CHEM:4171.

CHEM:5114 Chemical Systems Modeling 2 s.h.
Basic processes and techniques; these methods applied to systems relevant to students' own research. Recommendations: CHEM:3110 or CHEM:3120 or CHEM:4171.

CHEM:5115 Biophotonics 3 s.h.

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:5120 Electrochemistry of Polymer Films 1 s.h.
Use of electrochemical methods to characterize polymer and thin films; transport through polymer films and composites, electrochemistry of polymer films. Requirements: physical chemistry course.

CHEM:5150 Chemometrics 3 s.h.

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

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

CHEM:5202 Coordination Chemistry and Spectroscopy 1,3 s.h.

CHEM:5203 Organometallic Chemistry 3 s.h.

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
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:5290 Seminar: Inorganic Chemistry 0-1 s.h.

CHEM:5299 Special Topics in Inorganic Chemistry
Recommendations: CHEM:4270.

CHEM:5321 Spectroscopic Methods in Organic Chemistry

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 3 s.h.

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

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

CHEM:5401 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:5402 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 theory of molecular spectroscopy; time-dependent perturbation theory, selection rules, lineshapes; selected applications in microwave, vibrational (infrared and Raman), electronic, optical, and magnetic resonance spectroscopy. 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:5875 Perspectives in Biocatalysis 1-3 s.h.
Applied enzymology, protein design, structure-activity relationships, biosensor technology, microbial transformations, biodegradation of environmental pollutants. Requirements: graduate standing in a participating department supported by the Predoctoral Training Program in Biotechnology. Same as PHAR:5875, CBE:5875, CEE:5875, MICR:5875, BIOC:5875.

CHEM:5890 Research Frontiers in Chemistry 1 s.h.

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: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.