

Chemistry

Natural Sciences Division

Chemistry is often called the central science, overlapping significantly with biology, physics, psychology, mathematics, geology and engineering. All studies of matter at the molecular level (for example, biochemistry, molecular biology, pharmacology, neuroscience, nanoscience, computational chemistry, solid-state physics, geochemistry, the environmental sciences and material science and engineering) depend on the theories and methods of chemistry.

New Students

The first semester of introductory chemistry is offered at two levels.

CHEM 121 (Introductory Chemistry) is a lecture and discussion course intended to give students a thorough introduction to the fundamental concepts, theories and methods of chemistry; enrollment priority is given to first- and second-year students. CHEM 122 (Chemical Principles) is an accelerated lecture course covering a full year of general chemistry in one semester and is designed for students with previous study of chemistry. The prerequisite for CHEM 122 is a score of 4 or 5 on the AP chemistry test or the equivalent, determined by a placement exam administered during Orientation. CHEM 121 and 122 meet at the same time. CHEM 123 (Introductory Chemistry Lab I) is the accompanying lab course. It is highly recommended for students in CHEM 121 and is required for students in CHEM 122.

Students who have successfully completed CHEM 121 advance to CHEM 124 (Introductory Chemistry II), which continues the investigation of chemical principles as they apply to issues in modern chemistry, such as sustainability, neurochemistry, biochemistry and molecular medicine. CHEM 126 (Introductory Chemistry Lab II) is the accompanying lab course and is highly recommended for students in CHEM 124. Students who complete CHEM 122 may enroll directly into CHEM 231 (Organic Chemistry I) in the spring and get an early start on the upper-level curriculum.

Completion of one of the introductory lecture and lab sequences, either CHEM 121, 123, 124 and 126 or CHEM 122 and 123, is a prerequisite for enrolling in organic chemistry or any other advanced chemistry courses.

Students planning to complete medical school requirements should, in their first year, plan to take either the traditional introductory chemistry sequence CHEM 121, 123, 124 and 126 or the accelerated sequence CHEM 122, 123, 231 and 233. Please consult with your likely applicant medical schools regarding exact chemistry requirements. The following combinations should satisfy those requirements for courses in general chemistry:

Combination one

- CHEM 121: Introductory Chemistry
- CHEM 123: Introductory Chemistry Lab I
- CHEM 124: Introductory Chemistry II
- CHEM 126: Introductory Chemistry Lab II

Combination two

- CHEM 122: Chemical Principles
- CHEM 123: Introductory Chemistry Lab I
- CHEM 124: Introductory Chemistry II
- CHEM 126: Introductory Chemistry Lab II

Combination three

- CHEM 122: Chemical Principles
- CHEM 123: Introductory Chemistry Lab I

The organic chemistry requirements should be satisfied with:

- CHEM 231: Organic Chemistry I
- CHEM 232: Organic Chemistry II
- CHEM 233: Organic Chemistry Lab I
- CHEM 234: Organic Chemistry Lab II

The department also offers courses designed for students who are not planning to continue beyond one or two semesters of study. These non-majors courses, which are numbered below 120 and have no prerequisite, serve various purposes. CHEM 109 is part of the Neuroscience Concentration, and CHEM 110 is a core course for the Environmental Studies Concentration. Students wanting to complete the College requirements for 1 unit in the natural sciences can take these two courses. Non-majors courses do not serve as a prerequisite for any higher-numbered courses in the department.

The Curriculum

The chemistry curriculum begins with a series of courses covering introductory chemistry and organic chemistry in the first two years, then branches out to advanced topics in physical, inorganic, analytical and biochemistry. Because of this vertical structure, we advise students to begin their study of chemistry as soon as possible. This also helps capitalize on secondary-school preparation in math and science, the roots of college chemistry.

Students who are considering a chemistry, biochemistry or molecular biology major should plan to take CHEM 121 and 123 or CHEM 122 and 123 in their first semester and continue with the appropriate chemistry courses in the second semester, either CHEM 124 and 126 or CHEM 231 and 233. The chemistry major is rounded out with an offering of courses and labs on the major

subdisciplines of the field, along with seminar-style special-topics courses. Opportunities to work on independent research projects are available at all levels of the curriculum.

A capstone chemistry research seminar for seniors in the fall semester guides students through a self-study of an individual research topic, and the Senior Capstone in the spring semester involves preparing and presenting a talk on two research papers on the senior research topic.

Chemistry majors are well-prepared for professional employment or graduate study in chemistry, biochemistry and related fields; the health sciences such as medicine, dentistry and nursing; the veterinary sciences; secondary-school teaching; engineering; the environmental sciences; business and law; and public service. The major emphasizes the development of independent, critical thinking as well as problem-solving and communication skills. Our department is accredited by the American Chemical Society (ACS), and students may elect to receive a degree certified by the ACS (see below).

Numerous opportunities exist for students to participate in the life of the department through undertaking research with faculty members; participating in social and outreach activities; advising the department in the hiring and evaluation of faculty members; and other matters, and working as stockroom assistants, laboratory proctors and tutors.

Requirements for the Major

The minimum requirement for a chemistry major is eight to nine lecture courses and six to seven laboratory courses in the department, including the following:

1. One year of introductory chemistry lecture with lab:

Combination one

- CHEM 121: Introductory Chemistry
- CHEM 123: Introductory Chemistry Lab I
- CHEM 124: Introductory Chemistry II
- CHEM 126: Introductory Chemistry Lab II

Combination two

- CHEM 122: Chemical Principles (prerequisite: AP score of 4 or 5 or IB chemistry score of 5, 6 or 7 at the High Level)
- CHEM 123: Introductory Chemistry Lab I

2. One semester of organic chemistry lecture with lab:

- CHEM 231: Organic Chemistry I (prerequisite: CHEM 124 and CHEM 126)
- CHEM 233: Organic Chemistry Lab I (prerequisite: CHEM 122 and CHEM 123)

3. Required advanced lecture courses:

- CHEM 243: Inorganic Chemistry (prerequisite: CHEM 122 or 124)
- CHEM 335: Chemical Kinetics and Thermodynamics (prerequisite: CHEM 122 or 124)
- CHEM 341: Instrumental Analysis (prerequisite: CHEM 233)
- CHEM 475: Chemistry Research Seminar (prerequisite: senior standing)

4. Two elective advanced courses from the list below:

- CHEM 232: Organic Chemistry II (prerequisite: CHEM 231)
- CHEM 336: Quantum Chemistry (prerequisite: CHEM 122, 124 or 126)
- CHEM 401: Chemistry and Biochemistry Seminar (prerequisite: check specific section for more information)

Of special note: MATH 112 is highly recommended before enrolling in CHEM 335 or 336.

5. Four advanced labs from the list below:

- CHEM 234: Organic Chemistry Lab II
- CHEM 370: Advanced Lab: Computational Chemistry
- CHEM 371: Advanced Lab: Biochemistry
- CHEM 372: Advanced Lab: Inorganic
- CHEM 373: Advanced Lab: Organic
- CHEM 374: Advanced Lab: Spectroscopy

OR 0.5 units of CHEM 375 (Chemical Research) may replace one advanced lab

6. Senior Capstone

The Senior Capstone in chemistry has two components, one written and one oral. At the end of the fall semester, students submit a review paper on an assigned topic. During the spring semester, senior chemistry majors must prepare and present a talk on two research papers relating to their senior research topic. See the chair and the department website for more information about the Senior Capstone.

7. Additional Advanced Coursework & ACS Certified Degrees

What follows are recommendations and related information, not degree requirements.

Students planning to do graduate work in chemistry or related areas should take additional advanced courses in chemistry and the Natural Sciences Division, and partake in research opportunities during the school year and summer.

We encourage students to take upper-level courses in departments affiliated with chemistry (biology, environmental science, math, neuroscience, physics and psychology). With department

approval, one of the required advanced labs can be replaced with one unit of selected 200- or 300-level coursework in another department.

For a degree to be certified by the American Chemical Society, a student must complete the equivalent of two semesters of calculus; 1.5 units of introductory physics; the minimum chemistry major plus CHEM 256; and 1 unit of research in CHEM 375, including a comprehensive written report. Completion of honors satisfies the research requirement. Summer or off-campus research may satisfy the research requirement if it includes a comprehensive written report.

To be ACS certified, the major must be completed with a specific set of courses. To satisfy the ACS requirement for laboratory exposure to four of the five subdisciplines of chemistry (analytical, biochemistry, inorganic, organic and physical), two advanced lab requirements must be selected from 371, 372 and 374. To satisfy ACS requirements for in-depth coursework, four courses from 232, 336, 370, 373 or 401 must be taken. 401 may be taken twice, as long as it covers different topics.

For example, the degree would be ACS certified if electives were 232 and 336, and advanced labs were 370, 371, 372 and 373. It also would require 1.5 units of introductory physics, CHEM 256 and 1 unit of 375, as described above. In this example, 374 could substitute for 371 or 372, and 401 could substitute for 232, 336, 370 or 373.

The chemistry and biology departments offer interdisciplinary majors in biochemistry and molecular biology. Refer to the biochemistry and molecular biology section in the course catalog for more information.

Requirements for the Minor

The minor in chemistry requires a minimum of 2.5 units of credit earned in the chemistry curriculum; these include completion of CHEM 122 and 123 or CHEM 124 and 126; an advanced seminar, CHEM 401; and two upper-level lectures from CHEM 231, 232, 243, 256, 335, 336 or 341 or additional sections of 401. Certain majors require some of these courses; College policy does not allow counting any course toward both a major and a minor

Research

Students can gain research experience by participating in independent research under the supervision of a faculty advisor in CHEM 375. Although independent research is not required for the major, conducting research is a valuable educational experience, particularly for students planning to pursue graduate or medical training.

Honors

Departmental honors in chemistry involve demonstrating excellence in both depth and breadth of the discipline, through accomplishments on a specific research project and achievement in studying the principal areas of chemistry knowledge. Students wishing to pursue senior honors research in chemistry should apply to the chemistry department chair no later than April 15 of their junior year. See the chair and department website for more information about honors in chemistry.

Transfer Credit

Any transfer credit to be counted for the chemistry major or minor must be approved in advance by the department chair.

Courses in Chemistry

Neurochemistry

CHEM 109 CREDITS: 0.5

This course offers a description of the central nervous system's structure and function in terms of chemical interactions and reactions. Topics are developed through lectures, discussions and student presentations. Topics that may be covered include the chemistry related to neurocellular anatomy, neurotransmitters, psychoactive drugs and neurological disorders. This counts toward the neuroscience major. No prerequisite. Offered every two years.

Environmental Chemistry

CHEM 110 CREDITS: 0.5 QR

This course offers an introduction to the chemical basis of environmental issues and the environmental consequences of modern technology, with particular emphasis on air and water pollution. Topics include fossil fuels, nuclear power and solar energy, ozone depletion and the greenhouse effect, pollution and toxicology of heavy metals and pesticides, and environmental impact statements. These topics are developed through lectures, discussions and class demonstrations. This course is required for the Environmental Studies Concentration. This counts toward the additional skill course requirement for environmental studies. No prerequisite. Offered every two years.

Introductory Chemistry

CHEM 121 CREDITS: 0.5 QR

This course provides a thorough introduction to the fundamental concepts, theories and methodologies of chemistry. Topics may include stoichiometry, theories of molecular structure and bonding, the periodic table, quantum theory, acid-base chemistry, chemical equilibria and

thermodynamics. This course, or the equivalent, is required for the major. No prerequisite. Offered every fall semester.

Chemical Principles

CHEM 122 CREDITS: 0.5 QR

This course covers a full year of chemistry in one semester and is designed for students with previous study of chemistry. We explore and review key principles and methods from both CHEM 121 and 124. Prerequisite: AP score of 4 or 5 or placement exam. Corequisite: CHEM 123. Offered every fall semester.

Introductory Chemistry Lab I

CHEM 123 CREDITS: 0.25 QR

This laboratory course accompanies CHEM 121 and 122 with an introduction to modern experimental chemistry. Laboratory experiments explore inorganic synthesis, molecular structure and properties, and spectroscopy, with an emphasis on laboratory safety, computerized data acquisition and analysis, and the theory of analytical instrumentation. The laboratory work is organized around individual and team projects. Communication skills are developed through proper use of a laboratory notebook. One three-hour laboratory is held per week. Corequisite: CHEM 121 or 122. First-years and sophomores only. Offered every fall semester.

Introductory Chemistry II

CHEM 124 CREDITS: 0.5 QR

This lecture-discussion course continues the introductory chemistry sequence started in CHEM 121. We explore the chemical principles of molecular structure, bonding, reactivity, electrochemistry, kinetics and intermolecular forces. Chemical principles are explored in the context of current issues in the study or application of chemistry. Prerequisite: CHEM 121 or 122. Offered every spring semester.

Introductory Chemistry Lab II

CHEM 126 CREDITS: 0.25 QR

We create scientific knowledge through observation, mental models and careful design of experimental procedures. We invite you to explore and understand this process through a combination of practical experience and critical analysis. CHEM 123 and 126 are your introduction to modern experimental chemistry and are foundational to all upper-level chemistry laboratory courses. Course activities: analyze and design laboratory procedures, practice operation of laboratory equipment, assess and validate techniques, construct knowledge through discussion. Format: one three-hour laboratory session per week. Topics typically include gravimetric and volumetric techniques, standardization, titration, spectrophotometry, infrared spectroscopy, nuclear magnetic resonance spectroscopy, molecular modeling,

separations, chromatography, thermal analysis, kinetics, programming, data acquisition and data analysis. Prerequisite: CHEM 123. First-years and sophomores only. Offered every spring semester.

Organic Chemistry I

CHEM 231 CREDITS: 0.5

This lecture course offers a study of the chemical and physical properties of organic compounds. Theoretical principles are developed with particular emphasis on molecular structure and reaction mechanisms. The descriptive aspects of organic chemistry include strategies for synthesis and the study of compounds of biochemical interest. Prerequisite: grade of C+ or higher in both CHEM 124 and CHEM 126; or grade of C+ or higher in both CHEM 122 and CHEM 123. Offered every spring semester.

Organic Chemistry II

CHEM 232 CREDITS: 0.5

This course is a continuation of CHEM 231. This lecture course offers a study of the chemical and physical properties of organic compounds. Theoretical principles are developed with particular emphasis on molecular structure and reaction mechanisms. The descriptive aspects of organic chemistry include strategies for synthesis and the study of compounds of biochemical interest. This counts toward advanced course electives requirement for the major. Prerequisite: CHEM 231. Offered every fall semester.

Organic Chemistry Lab I

CHEM 233 CREDITS: 0.25 QR

This laboratory course introduces fundamental methods in organic chemistry research and complements the topics covered in the lecture course, CHEM 231. This is achieved by carrying out experiments and research projects involving topics such as isolation of a natural product, oxidation and reduction reactions, and reactions of alkenes. The techniques include liquid extraction, distillation, recrystallization and thin-layer and gas chromatography. Compounds are identified and assessed for purity by melting-point determination, refractometry, gas chromatography, and infrared and nuclear magnetic resonance spectroscopy. Appropriate record-keeping on laboratory notebooks and writing laboratory reports is emphasized. This course is required for the major. Prerequisite: CHEM 126; or CHEM 122 and 123. Corequisite: CHEM 231. Offered every spring semester.

Organic Chemistry Lab II

CHEM 234 CREDITS: 0.25 QR

This laboratory course extends and applies the techniques developed in CHEM 233 to more advanced experiments in organic synthesis including open-ended experiments derived from current research projects. A particular emphasis is placed on using chemistry databases,

experimental design and planning, laboratory notebooks and record-keeping, analytical and preparative chromatography, advanced NMR techniques (2-D) and writing research laboratory reports. Upon successful completion of the two-course organic chemistry lab sequence (CHEM 233/234), students have the skills needed to thrive in a synthetic organic chemistry research laboratory. This counts towards the advanced lab electives requirement for the major. Prerequisite: CHEM 233. Corequisite: CHEM 232. Offered every fall semester.

Inorganic Chemistry

CHEM 243 CREDITS: 0.5

This course provides a foundation in the principles of structure, bonding and reactivity in inorganic compounds and materials. We emphasize the physical properties that make these materials useful in functional devices and biological systems. Possible applications include semiconductor devices, solar-energy conversion, battery technology, and photonic devices and sensors. Throughout our explorations, we build models, both metaphorical and mathematical, that guide chemists in the design, use and analysis of materials. Prerequisite: CHEM 122, 124 or 231. Offered every fall semester.

Biochemistry

CHEM 256 CREDITS: 0.5

This course is a study of the structure and function of biologically important compounds. Topics include proteins, enzymes, intermediary metabolism and electron transport with emphasis on thermodynamic and kinetic analysis of biochemical systems. Prerequisite: CHEM 232. Offered every spring semester.

Chemical Kinetics and Thermodynamics

CHEM 335 CREDITS: 0.5 QR

This course presents a study of chemical kinetics and chemical thermodynamics. Specific topics include rate laws and reaction mechanisms, reaction-rate theories, the laws of thermodynamics, thermochemistry, properties of solutions, and equilibrium. Applications are drawn from organic and inorganic chemistry, as well as biochemistry. This counts toward the major. MATH 112 is highly recommended. Prerequisite: CHEM 122 or 124. Offered every fall semester.

Quantum Chemistry

CHEM 336 CREDITS: 0.5 QR

This course presents a study of quantum mechanics as applied to chemistry. Specific topics include general quantum theory; the time-independent Schrödinger equation applied to electronic, vibrational and rotational energy states; valence bond and molecular orbital theory; and molecular symmetry. This counts toward advanced course elective requirement for the major. MATH 112 is highly recommended. Prerequisite: CHEM 122, 124 or 126. Offered every two years for the spring semester.

Instrumental Analysis

CHEM 341 CREDITS: 0.5 QR

Is your water safe? How do you know what compounds are in your water, food, body and local environment? How do you measure and quantify these compounds? How do you convince yourself that your measurements are valid or invalid? CHEM 341 explores the theory and practice of quantitative chemical analysis. Students apply principles of measurement, instrument design and data analysis to instrumental methods. Topics include statistics of measurement error and uncertainty, calibration, spectrochemical methods, electrochemical analysis and analytical separations including chromatography, spectroscopic, electrochemical and chromatographic methods. According to student interest, additional topics may include environmental analysis, biochemical assays, food quality and consumer safety. Students develop scientific communication skills through writing and oral presentations. This counts towards the major. Prerequisite: CHEM 233. Offered every spring semester.

Advanced Lab: Computational Chemistry

CHEM 370 CREDITS: 0.25

This advanced laboratory course focuses on using computational methods to understand chemistry and biochemistry. Part of the course concentrates on using these methods to understand and visualize molecular structure, and part concentrates on using numerical methods to understand the kinetics and mechanisms associated with reaction systems. Computational work involves both short experiments done individually and a larger research project conducted in conjunction with classmates. This course meets for one three-hour laboratory period per week. Prerequisite or corequisite: CHEM 335. Not offered every year.

Advanced Lab: Biochemistry

CHEM 371 CREDITS: 0.25

This course is an introduction to fundamental laboratory techniques in biochemistry. The focus of the course is the isolation, purification, characterization and detailed kinetic analysis of an enzyme of interest. This course meets for one three-hour laboratory period per week. This counts toward advanced lab elective requirement for the major. Prerequisite or corequisite: CHEM 256, and declared major in chemistry, biochemistry, or molecular biology.. Offered every spring semester.

Advanced Lab: Inorganic

CHEM 372 CREDITS: 0.25

In this laboratory course, students engage in projects that integrate inorganic synthesis, analytical instrumentation, and physical measurement, focusing on coordination complexes. The course meets for one three-hour laboratory period per week. This counts toward advanced lab elective requirement for the major. Prerequisite: CHEM 234. Not offered every year.

Advanced Lab: Organic

CHEM 373 CREDITS: 0.25

In this laboratory course, students engage in multiweek, multistep projects that integrate both modern organic synthesis and advanced high-field nuclear magnetic resonance techniques. This course meets for one three-hour laboratory period per week. This counts toward advanced lab elective requirement for the major. Prerequisite: CHEM 234. Not offered every year.

Advanced Lab: Spectroscopy

CHEM 374 CREDITS: 0.25

This advanced laboratory course focuses on spectroscopy instrumentation and data analysis. UV/Vis, fluorescence and laser spectroscopies are used to solve research questions involving kinetics, thermodynamics and molecular structure. Experiments are intended to complement course work in CHEM 341, 335 and 336, but these courses may be taken in any order. This course meets for one three-hour laboratory period per week. This counts toward advanced lab elective requirement for the major. Prerequisite: CHEM 122 and 123 or 126. Offered every year.

Chemical Research

CHEM 375 CREDITS: 0.25 - 0.5

Section 01 (0.25 unit): Students engage in independent research under the direction of a faculty mentor. The time requirement is at least three hours in lab per week. Students learn to search literature and give professional presentations. This course also provides an introduction to scientific writing. More details can be obtained from the department chair. Permission of instructor required. Offered every semester.

Section 02 (0.5 unit): This section is a prerequisite to CHEM 497 and 498. The time commitment is six to eight hours per week in lab. Students learn to search literature and give professional presentations as well as to write scientifically. More details can be obtained from the department chair. This counts toward advanced lab elective for the major. Permission of instructor required. Offered every semester.

Chemistry and Biochemistry Seminar

CHEM 401 CREDITS: 0.5

Advanced selected topics in advanced chemistry and biochemistry are explored with an emphasis on reading and discussing current scientific research and literature. Topics covered vary by faculty interest each semester and typically relate to interesting applications or emerging techniques within organic, biophysical, biochemical, materials or analytical chemistry. Offered every semester, sections will change. Inquire with the chair and look for announcements for the specific topic in a given semester. Please see the schedule of courses each semester for the section being taught. This counts toward advanced course elective requirement for the major. Offered every semester.

Chemistry Research Seminar

CHEM 475 CREDITS: 0.25

This is a required course for all chemistry majors, including those involved in independent research. The course covers topics relating to chemistry research. Weekly meetings involve searching chemistry literature; analyzing primary research articles; and discussing ethics, trends, funding and other issues relating to chemistry research. During the semester, students give written and oral presentations of primary research articles. This counts toward a required advanced lecture course requirement for the major. No prerequisites. Senior standing. Offered every fall semester.

Individual Study

CHEM 493 CREDITS: 0.25 - 0.5

Individual study in chemistry is intended to supplement, not take the place of, coursework. For that reason, such study cannot be used to fulfill requirements for the major or minor. To enroll in an individual study, a student must identify a member of the chemistry department willing to direct the project and obtain the approval of the department chair. At a minimum, the department expects a student to meet regularly with his or her instructor for at least one hour per week. Because students must enroll for individual studies by the end of the seventh class day of each semester, they should begin discussion of the proposed individual study by the semester before, so that there is time to devise the proposal and seek departmental approval.

Senior Honors

CHEM 497 CREDITS: 0.5

The emphasis is on independent research in collaboration with a faculty mentor, culminating with a thesis that is defended orally to an outside examiner. See department chair or website for full description. Permission of instructor and department chair required. Prerequisite: GPA of at least 3.2, enrollment in Section 02 of CHEM 375.

Senior Honors

CHEM 498 CREDITS: 0.5

The emphasis is on independent research in collaboration with a faculty mentor, culminating with a thesis that is defended orally to an outside examiner. See department chair or website for full description. Permission of instructor and department chair required. Prerequisite: GPA of at least 3.2, enrollment in Section 02 of CHEM 375.