# Chemistry

*Natural Sciences*

## Requirements

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 is a lecture-and-discussion course intended for students needing a thorough introduction to the fundamental concepts, theories, and methods of chemistry; enrollment priority is given to first- and second-year students. CHEM 122 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. These two courses meet at the same time. CHEM 123 is the accompanying lab course, highly recommended for students in CHEM 121 and required for students in CHEM 122. First-year students enrolling in any introductory chemistry course must complete the chemistry readiness test and survey during orientation.

Students who have successfully completed CHEM 121 can then choose a second-semester lecture-and-discussion course based on their particular interests. CHEM 124 continues the investigation of chemical principles as they apply to issues in modern chemistry, such as sustainability, neurochemistry, biochemistry, and molecular medicine. Students who complete CHEM 122 may enroll directly into CHEM 243 in the spring, and get an early start on the upper-level curriculum. These two courses meet at the same time. CHEM 126 is the accompanying lab course, highly recommended for students in CHEM 124 and a co- or prerequisite for students in CHEM 243.

Completion of a full-year sequence of introductory chemistry lecture and lab courses (1.5 units) is a prerequisite for enrolling in organic chemistry or any other advanced chemistry courses and will satisfy medical-school requirements for a course in general chemistry. Transfer students and those with Advanced Placement credit or exceptionally strong secondary-school preparation in chemistry may be invited by the department, after completing the chemistry readiness test and survey, to begin their studies in organic chemistry.

The department also offers several 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 prerequisites, serve various purposes. CHEM 109 is a required core course for the concentration in neuroscience, and CHEM 108 or CHEM 110 is a required core course for the concentration in

environmental studies. Students wanting to complete the College requirements for 1 unit in the natural sciences can take any two of these, and CHEM 108 satisfies the College quantitative reasoning (QR) requirement. Non-majors courses do not serve as a prerequisite for any higher-numbered courses in the department.

**The Chemistry 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, and analytical chemistry and biochemistry. Because of this vertical structure, we advise students to begin their study of chemistry as soon as possible in order to build upon their secondary-school preparation in math and science, the roots of college chemistry. Students who are considering a chemistry, biochemistry, or molecular biology major or who are planning to complete premedicine requirements should plan to take a full year of introductory lecture and lab courses (see below) in their first year.

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. 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 Exercise in the spring semester involves preparing and presenting a thirty-minute talk on two research papers on the senior research topic. Opportunities to work on independent research projects are available at all levels of the curriculum.

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 (1) undertaking research with faculty members, (2) participating in social and outreach activities, (3) advising the department in the hiring and evaluation of faculty members and other matters, and (4) working as stockroom assistants, laboratory proctors, paper graders, and tutors.

**Requirements for the Major**

The minimum requirement for a chemistry major is 6 units of credit in the department, including the following:

**1. One year of introductory chemistry lecture with lab:**

CHEM 122
CHEM 123 and CHEM 126

*or*

CHEM 121 and CHEM 124
CHEM 123 and CHEM 126

**2. One semester of organic chemistry with lab (0.75 unit):**

CHEM 231 with Chem 233

**3. Three advanced courses (1.5 units):**

CHEM 243
CHEM 335
CHEM 341

**4. Two elective advanced courses (1.0 unit)**:

CHEM 232
CHEM 336
CHEM 401

**5. Four advanced labs (1.0 unit):**

CHEM 234
CHEM 370, 371, 372, 374

0.5 unit of CHEM 375 may replace one advanced lab (.25 units)

**6. CHEM 475 Chemistry Research Seminar (.25 units) and the Senior Exercise**

In addition, a year of introductory physics lecture (PHYS 130, 135 or 140, 145) with lab (PHYS 141, 146), and Calculus B (MATH 112) are highly recommended. Those 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. For a degree to be certified by the American Chemical Society, a student must complete 1.5 units of introductory physics, the minimum chemistry major plus CHEM 256 and 1.0 unit of research in CHEM 375.

The chemistry and biology departments offer interdisciplinary majors in biochemistry and molecular biology. Refer to the biochemistry and molecular biology section in this catalog for descriptions and course requirements. We encourage students to take upper-level courses in departments affiliated with chemistry (biology, physics, mathematics, neuroscience, or psychology). With department approval, one of the required advanced labs can be replaced with 1.0 unit of selected 200- or 300-level coursework in another department.

**Senior Exercise**

The Senior Exercise 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 thirty-minute talk on two research papers relating to their senior research topic. See the department chair and Web site for more information.

**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 department chair and Web site for more information.

**Requirements for the Chemistry Minor**

The minor in chemistry requires a minimum of 2.50 units of credit earned in the chemistry curriculum; these include completion of introductory chemistry (CHEM 122 or CHEM 124), the introductory laboratories (CHEM 123 and CHEM 126), an advanced seminar (CHEM 401), and two upper-level lectures from: CHEM 231, 232, 243, 256, 335, 336, 341, or additional sections of 401.

# Courses

**CHEM 108 SOLAR ENERGY**

*Credit: 0.5 QR*

The exigencies of peak oil, global warming, and unsustainable growth in energy consumption have sparked a quest for clean, abundant, renewable energy to replace fossil fuels. This course explores the chemistry of fossil fuels and potential solar-energy alternatives, ranging from biofuels to solar panels to hydrogen. Chemical principles such as reaction stoichiometry, molecular structure, thermochemistry, catalysis, energy quantization, and electrochemistry will be learned in the context of investigating solar radiation, greenhouse gases, photovoltaics, artificial photosynthesis, fuel cells, and the production and storage of hydrogen. This course is a required core course for the Environmental Studies Concentration. This course plus CHEM 109 or CHEM 110 fulfills the 1 unit natural science distribution requirement.

Instructor: Cummings

**CHEM 109 NEUROCHEMISTRY**

*Credit: 0.5*

This course offers a description of the nervous system's structure and function in terms of molecular processes. Topics are developed through lectures, discussions, and student presentations. The course begins with a brief introduction to general and organic chemistry, then continues with the following topics: neurocellular anatomy and the biochemistry of cell neurotransmitters and receptors, and the biochemistry of psychoactive drugs and neurological disorders. This course is a required core course for

the Neuroscience Concentration, and with CHEM 108 or CHEM 110 fulfills the natural science distribution requirement. No prerequisite.

Instructor: Hemkin

**CHEM 110 ENVIRONMENTAL CHEMISTRY**

*Credit: 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 will be developed through lectures, discussions, and class demonstrations. This course is a required core course for the Environmental Studies Concentration, and with CHEM 108 or CHEM 109 fulfills the natural science distribution requirement. No prerequisite.

Instructor: Staff

**CHEM 121 INTRODUCTORY CHEMISTRY**

*Credit: 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, acid-base chemistry, chemical equilibria, and thermodynamics. This course provides a basis for the further study of chemistry. The format is lecture and discussion. Prerequisite: first-year students: chemistry readiness test and survey; none for other students.

Instructor: Staff

**CHEM 122 CHEMICAL PRINCIPLES**

*Credit: 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 will explore and review key principles and methods from both CHEM 121 and CHEM 124. Prerequisite: Placement exam. Corequisite: CHEM 123.

Instructor: Staff

**CHEM 123 INTRODUCTORY CHEMISTRY LAB I**

*Credit: 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. Juniors and seniors may enroll with permission of department chair.

**CHEM 124 INTRODUCTORY CHEMISTRY II**

*Credit: 0.5 QR*

This lecture-discussion course continues the introductory chemistry sequence started in CHEM 121. We will explore the chemical principles of molecular structure, bonding, reactivity, electrochemistry, kinetics, and intermolecular forces. Prerequisite: CHEM 121 or permission of instructor.

Biophysical and Medicinal Chemistry section

Chemical principles are explored in the context of biomolecules and molecular approaches to medicine.

Current Topics in Chemistry section

Chemistry principles are explored in the context of current issues in the study or application of chemistry. Topics include: sustainability, molecular neuroscience, environmental chemistry, biomedical technology, and renewable energy.

Instructor: Staff

**CHEM 126 INTRODUCTORY CHEMISTRY LAB II**

*Credit: 0.25 QR*

This lab is an experimental course to accompany CHEM 124 or 243. One three-hour laboratory session will be held per week. Juniors and seniors may enroll with permission of department chair. Prerequisite: CHEM 123.

Biophysical and Medicinal Chemistry Lab sections

Laboratory experiments involve the application of chemical principles and techniques to systems of biological and medicinal importance. Possible experiments include: synthesis of aspirin, enzyme kinetics, and chromatographic analysis.

Nanoscience Lab section

Laboratory experiments involve the synthesis of functional materials, the analysis of their properties, and the assembly of materials into working devices. Possible experiments include: making solar cells, synthesis of nanocrystalline materials, quantum dots, and an independent project.

**CHEM 231 ORGANIC CHEMISTRY I**

*Credit: 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: CHEM 126 or permission of department chair. Also requires a grade of C+ or higher in CHEM 121 or CHEM 122.

**CHEM 232 ORGANIC CHEMISTRY II**

*Credit: 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. Prerequisite: CHEM 232.

**CHEM 233 ORGANIC CHEMISTRY LAB I**

*Credit: 0.25 QR*

This laboratory course introduces fundamental methods of purification such as extraction, distillation, recrystallization, and column chromatography. Experiments include the isolation of a natural product, oxidation and reduction reactions, and an examination of E1 and E2 reactions. Compounds are identified and assessed for purity by melting point determination, refractometry, gas chromatography, infrared spectroscopy, and proton nuclear magnetic resonance. Corequisite: CHEM 231.

**CHEM 234 ORGANIC CHEMISTRY LAB II**

*Credit: 0.25 QR*

This laboratory course focuses on the chemistry of dienes, carbonyl compounds, and aromatic compounds. Techniques and instrumentation include thin-layer chromatography, infrared spectroscopy, and nuclear magnetic resonance spectroscopy. The focus of the semester is a seven-step convergent synthesis to be conducted in a research-like manner. Prerequisite: CHEM 233. Corequisite: CHEM 232.

**CHEM 243 INORGANIC CHEMISTRY**

*Credit: 0.5*

This course provides a foundation in the principles of structure, bonding, and reactivity in inorganic compounds and materials. We will emphasize the physical properties that make these materials useful in functional devices and biological systems. Possible applications may include semiconductor devices, solar-energy conversion, battery technology, photonic devices, and sensors. Throughout our explorations, we

will build models, both metaphorical and mathematical, that guide chemists in the design, use and analysis of materials. Prerequisite: CHEM 122, 124, or 231 or permission of instructor.

Instructor: Staff

**CHEM 256 BIOCHEMISTRY**

*Credit: 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 or corequisite: CHEM 232.

Instructor: Staff

**CHEM 335 CHEMICAL KINETICS AND THERMODYNAMICS**

*Credit: 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 will be drawn from organic and inorganic chemistry, as well as biochemistry. Prerequisite: CHEM 126. MATH 112 is highly recommended.

Instructor: Staff

**CHEM 336 QUANTUM CHEMISTRY**

*Credit: 0.5 QR*

This course presents a study of quantum mechanics as applied to chemistry. Specific topics include general quantum theory; the time-independent Schrodinger equation applied to electronic, vibrational, and rotational energy states; valence bond and molecular orbital theory; and molecular symmetry. This course is offered every other year. Prerequisite: CHEM 126. Corequisite: one year of physics. MATH 112 is highly recommended.

Instructor: Keller

**CHEM 341 INSTRUMENTAL ANALYSIS**

*Credit: 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 is a hybrid lecture/laboratory course on the theory and practice of quantitative chemical analysis. Students will apply fundamental principles of measurement, instrument design, and data analysis to instrumental methods. After applying these principles to a sequence of laboratory experiments, students will then develop and evaluate their own

instrumental methods. Topics include spectroscopic, electrochemical, and chromatographic methods. According to student interest, additional topics may include environmental analysis, biochemical assays, food quality, and consumer safety. Prerequisite: four semesters of CHEM lab or permission of instructor.

Instructor: Staff

**CHEM 370 ADVANCED LAB: COMPUTATIONAL CHEMISTRY**

*Credit: 0.25*

This advanced laboratory course focuses on using computational methods to understand chemistry and biochemistry. Part of the course will concentrate on using these methods to understand and visualize molecular structure, and part of the course will concentrate on using numerical methods to understand the kinetics and mechanisms associated with reaction systems. Computational work will involve both short experiments done individually and a larger research project that will be conducted in conjunction with classmates. This course meets for one three-hour laboratory period per week. Prerequisite or corequisite: CHEM 335 or permission of instructor.

Instructor: Hemkin

**CHEM 371 ADVANCED LAB: BIOCHEMISTRY**
*Credit: 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 alkaline phosphatase from E. coli. This course meets for one three-hour laboratory period per week. Prerequisite or corequisite: CHEM 256.

Instructor: Staff

**CHEM 372 ADVANCED LAB: INORGANIC**
*Credit: 0.25*

In this laboratory course, students will 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. Prerequisite: CHEM 234 or permission of instructor.

Instructor: Cummings

**CHEM 373 ADVANCED LAB: ORGANIC**
*Credit: 0.25*

In this laboratory course, students will 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. Prerequisite: CHEM 234.

Instructor: Getzler

**CHEM 374 ADVANCED LAB: SPECTROSCOPY**

*Credit: 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 Instrumental Analysis (CHEM 341), Chemical Kinetics and Thermodynamics (CHEM 335), and Quantum Chemistry (CHEM 336), but these courses may be taken in any order. This course meets for one three-hour laboratory period per week. Prerequisite: CHEM 126.

Instructor: Keller

**CHEM 375 CHEMICAL RESEARCH**

*Credit: 0.25-0.5*

Section 01 (.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 will learn to search the literature and give professional presentations. This course also provides an introduction to scientific writing. More details can be obtained from the department chair. Prerequisite: permission of instructor.

Section 02 (.5 unit). This section is a prerequisite to Chemistry 497-498 (Senior Honors). The time commitment is six to eight hours per week in lab. Students will learn to search the literature and give professional scientific presentations as well as to write scientifically. More details can be obtained from the department chair. Prerequisite: permission of instructor.

**CHEM 401 CHEMISTRY AND BIOCHEMISTRY SEMINAR**

*Credit: 0.5*

Selected topics in advanced chemistry and biochemistry are explored with an emphasis on reading and discussing current scientific research and literature. Prerequisite: CHEM 234 or permission of instructor unless otherwise indicated.

Biophysical Chemistry Seminar

Section 01: This seminar focuses on understanding some of the thermodynamics associated with bio-macromolecules like proteins and DNA. We may examine transport processes, the thermodynamics that characterize the intra- and intermolecular interactions, and some of the statistical models that are used to understand folding and structural transitions.

Advanced Organic Chemistry Seminar

Section 02: Selected topics in organic chemistry are covered with an emphasis on advanced spectral methods of identifying organic compounds and modern methods of organic synthesis. *Copy and paste following url to access online application for PI.*

https://docs.google.com/a/kenyon.edu/forms/d/15omFVZFGtTkDJyVYCOZT-g8JN16LVU5W5aKDwI_fxqs/viewform

Art and Chemistry Seminar

Section 03: This seminar focuses on understanding some of the relationships between art and chemistry, for example, the chemical basis of pigmentation and the use of chemical techniques to identify works from unknown origins.

Chemical Biology Seminar

Section 04: Chemical biology is a scientific discipline at the interface of chemistry and biology. This seminar explores the applications of chemical techniques to manipulate and investigate biological systems. Using resources including current literature, this course covers the chemical techniques used to understand and treat diseases such as cancer and viral, microbial, and neurodegenerative diseases.

Hydrogen Energy Systems Seminar

Section 05: In the search for abundant, renewable, and carbon-free energy sources, scientists are on a quest to develop inexpensive and renewable methods to produce, store, and use hydrogen fuel. This seminar explores various aspects of hydrogen energy systems, including: the development of a "hydrogen economy" infrastructure; hydrogen production from fossil fuel reforming and from water splitting; solid-state storage materials; hydrogen fuel cell operation and design; and advanced research directions in hydrogen energy.

Enzyme Mechanism Seminar

Section 06: Over the past two decades, our collective knowledge base in chemical biology has exploded. One powerful approach to organizing this enormous body of information is to recognize that nature is bound by the same principles that govern chemistry. Students will explore the mechanistic logic behind biological pathways and examine the technical aspects of how reasonable enzyme mechanisms are determined.

Emerging Techniques in Biological Chemistry

Section 07: Recent advances in biotechnology have had a huge impact on the ability to detect and analyze micro- and nano-size biomolecules with greater accuracy. This literature-based course will look at several emerging techniques and instrumentation that are being used to advance research in topics such as protein dynamics, single molecule detection, and metabolic engineering in areas that range from neuroscience to biofuels.

Advanced Biochemistry

Section 08: We will explore the molecular details of key metabolic pathways, biological signaling, and molecular transport machinery.The topics discussed will be valuable to students on a trajectory toward careers in life science research and medicine. Students will engage the primary literature to explore

current research related to the topics discussed. This course will dovetail with and extend the topics taught in Biochemistry and CHEM 256. Prerequisite: CHEM 256

**CHEM 475 CHEMISTRY RESEARCH SEMINAR**

*Credit: 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 will involve (1) searching chemistry literature, (2) analyzing primary research articles, and (3) discussing ethics, trends, funding, and other issues relating to chemistry research. During the semester, students will give written and oral presentations of primary research articles. Prerequisite: senior standing.

Instructor: Staff

**CHEM 493 INDIVIDUAL STUDY**

*Credit: 0.25-0.5*

Individual study in chemistry is intended to supplement, not take the place of, coursework. For that reason, such study cannot normally be used to fulfill requirements for the major. Typically, an individual study will count as .25 unit of credit, yet it may be designated .5 unit in special cases.

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.

**CHEM 497 SENIOR HONORS**

*Credit: 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. Prerequisite: GPA of at least 3.2, enrollment in Section 02 of CHEM 375 or CHEM 376, and permission of department chair. See department chair or Web site for full description.

**CHEM 498 SENIOR HONORS**

*Credit: 0.5*

See course description for CHEM 497.