Chemistry

For students interested in discovering insights into nature and exploring new ways to meet the needs of our technological society and new methods for creating novel compounds and useful materials, chemistry is an excellent major to pursue.

Chemistry is a multifaceted science that extends into biology, medicine, physics, mathematics, business and commerce. Studying chemistry provides the opportunity to explore the structure and constitution of the microworlds of atoms and molecules, the chemical and physical transformations that occur, and the principles that govern these changes.

Our program provides a strong foundation in the core areas of chemistry: organic, physical, inorganic, nuclear and theoretical. Special emphases in the department include such emerging interdisciplinary fields as organometallic, bioorganic, biophysical, macromolecular, polymer, environmental and materials chemistry. The department has close research ties with the departments of Physics; Earth and Planetary Sciences; Biology; Biomedical Engineering; Energy, Environmental & Chemical Engineering; and Mechanical Engineering & Materials Science. It also works closely with various departments at the Washington University School of Medicine.

Undergraduate majors in chemistry study chemistry with renowned scientists who are teacher-scholars dedicated to the students' learning experience. The department is small, and it has world-class instruments and facilities, which allows students to receive individualized instruction and to participate in cutting-edge science. Each student works closely with a faculty member to design and carry out an original research project. Students may participate in interdisciplinary research at the School of Medicine or the McKelvey School of Engineering. Research internships at local companies can also be arranged.

A variety of creative and productive careers are available to graduates with a degree in chemistry. Graduates may pursue a career in chemistry or in such related professions as biochemistry, medicine and chemical engineering. Most students continue on to graduate or medical school, and some go on to business or law school. Positions in government, industry and education are also available.

Phone: 314-935-6530
Email: chemistry@wustl.edu
Website: http://chemistry.wustl.edu

Faculty

Chair
William E. Buhro (https://chemistry.wustl.edu/people/william-buhro)
George E. Pake Professor of Arts & Sciences
PhD, University of California, Los Angeles

Endowed Professors
Regina F. Frey (https://chemistry.wustl.edu/people/gina-frey)
Florence Moog Professor of STEM Education
Professor, Department of Chemistry
PhD, University of Utah

Gary J. Patti (https://chemistry.wustl.edu/people/gary-patti)
Michael and Tana Powell Associate Professor of Chemistry
PhD, Washington University

Holden Thorp (https://chemistry.wustl.edu/people/holden-thorp)
Provost
Rita Levi-Montalcini Distinguished University Professor
PhD, California Institute of Technology

William B. Tolman (https://chemistry.wustl.edu/people/william-tolman)
William Greenleaf Eliot Professor of Chemistry
Associate Dean of Research
PhD, University of California, Berkeley

Professors
John R. Bleeke (https://chemistry.wustl.edu/people/john-bleeke)
PhD, Cornell University

Michael L. Gross (https://chemistry.wustl.edu/people/michael-l-gross)
PhD, University of Minnesota

Sophia E. Hayes (https://chemistry.wustl.edu/people/sophia-e-hayes)
PhD, University of California, Santa Barbara

J. Dewey Holten (https://chemistry.wustl.edu/people/dewey-holten)
PhD, University of Washington

Richard A. Loomis (https://chemistry.wustl.edu/people/richard-loomis)
PhD, University of Pennsylvania

Kevin D. Moeller (https://chemistry.wustl.edu/people/kevin-moeller)
PhD, University of California, Santa Barbara

Jay Ponder (https://chemistry.wustl.edu/people/jay-ponder)
PhD, Harvard University

Demetrios G. Sarantites (https://chemistry.wustl.edu/people/demetrios-sarantites)
PhD, Massachusetts Institute of Technology
Lee G. Sobotka (https://chemistry.wustl.edu/people/lee-sobotka)
PhD, University of California, Berkeley

John-Stephen Taylor (https://chemistry.wustl.edu/people/john-stephen-taylor)
PhD, Columbia University

Mark S. Wrighton (https://chemistry.wustl.edu/people/mark-stephen-wrighton)
Chancellor
PhD, California Institute of Technology

Associate Professors
Vladimir B. Birman (https://chemistry.wustl.edu/people/vladimir-birman)
PhD, University of Chicago

Richard Mabbs (https://chemistry.wustl.edu/people/richard-mabbs)
PhD, University of Nottingham (U.K.)

Timothy Wencewicz (https://chemistry.wustl.edu/people/timothy-wencewicz)
PhD, University of Notre Dame

Assistant Professors
Jonathan Barnes (https://chemistry.wustl.edu/people/jonathan-barnes)
PhD, Northwestern University

Julio D’Arcy (https://chemistry.wustl.edu/people/julio-m-darcy)
PhD, University of California, Los Angeles

Joseph Fournier (https://chemistry.wustl.edu/people/joseph-fournier)
PhD, Yale University

Meredith Jackrel (https://chemistry.wustl.edu/people/meredith-jackrel)
PhD, Yale University

Bryce Sadtler (https://chemistry.wustl.edu/people/bryce-sadtler)
PhD, University of California, Berkeley

Joint Professor
Richard W. Gross (https://chemistry.wustl.edu/people/michael-l-gross)
PhD, Washington University
(Internal Medicine)

Majors
The Major in Chemistry

Total units required: 53-62

Required courses: To prepare for a major in chemistry, students will take the following:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chem 111A</td>
<td>General Chemistry I</td>
<td>3</td>
</tr>
<tr>
<td>Chem 112A</td>
<td>General Chemistry II</td>
<td>3</td>
</tr>
<tr>
<td>Chem 151</td>
<td>General Chemistry Laboratory I</td>
<td>2</td>
</tr>
<tr>
<td>Chem 152</td>
<td>General Chemistry Laboratory II</td>
<td>2</td>
</tr>
<tr>
<td>Chem 261</td>
<td>Organic Chemistry I with Lab</td>
<td>4</td>
</tr>
<tr>
<td>Chem 262</td>
<td>Organic Chemistry II with Lab</td>
<td>4</td>
</tr>
<tr>
<td>Math 131</td>
<td>Calculus I</td>
<td>3</td>
</tr>
<tr>
<td>Physics 191</td>
<td>Physics I</td>
<td>3</td>
</tr>
<tr>
<td>Physics 191L</td>
<td>Physics I Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>Physics 192</td>
<td>Physics II</td>
<td>3</td>
</tr>
<tr>
<td>Physics 192L</td>
<td>Physics II Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>Math 132</td>
<td>Calculus II</td>
<td>3</td>
</tr>
<tr>
<td>Math 233</td>
<td>Calculus III</td>
<td>3</td>
</tr>
<tr>
<td>Total Units</td>
<td></td>
<td>35</td>
</tr>
</tbody>
</table>

Note: In certain instances, students may substitute Chem 105 and Chem 106 for Chem 111A and Chem 112A. Please consult the department's director of undergraduate studies for details.

Majors in chemistry must take a minimum of 18 units of advanced courses in chemistry or biochemistry, among which the following must be included:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chem 401</td>
<td>Physical Chemistry I</td>
<td>3</td>
</tr>
<tr>
<td>Chem 402</td>
<td>Physical Chemistry II</td>
<td>3</td>
</tr>
<tr>
<td>Chem 461</td>
<td>Inorganic Chemistry</td>
<td>3</td>
</tr>
<tr>
<td>Total Units</td>
<td></td>
<td>9</td>
</tr>
</tbody>
</table>

In addition, 9 units in chemistry at the 300 level or above must be taken (not including Chem 490 Introduction to Research or Chem 495 Advanced Undergraduate Research in Chemistry). Biol 451 General Biochemistry may be used to complete 3 of the required 9 units.

At least 3 of these 9 advanced units must be in a laboratory course chosen from the following list:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chem 358</td>
<td>Organic Chemistry Laboratory II</td>
<td>4</td>
</tr>
<tr>
<td>Chem 435</td>
<td>Nuclear and Radiochemistry Lab</td>
<td>3</td>
</tr>
<tr>
<td>Chem 445</td>
<td>Instrumental Methods: Physical Chemistry</td>
<td>3</td>
</tr>
<tr>
<td>Chem 470</td>
<td>Inorganic Chemistry Laboratory</td>
<td>3</td>
</tr>
</tbody>
</table>

Physics 217 Introduction to Quantum Physics and additional mathematics courses are also recommended. Chem 181 First-Year Opportunity: Applications in Chemistry, a seminar to introduce first-year students to research activities in the department, is optional. A working knowledge of computer programming and a foreign language, such as German or Russian, is encouraged but not required.
Students have the advantage of planning their course program with their adviser in accordance with personal interests. Some graduate courses are also available to seniors.

All chemistry course work must be taken in residence at Washington University to be applied toward the chemistry major. A minimum grade of C- must be earned in each course to count toward the chemistry major.

**Note:** Per the College of Arts & Sciences guidelines, for students who also pursue a minor or more than one major or minor program, only introductory (100- and 200-level) courses may be counted, when relevant, toward the requirements of both programs. All advanced (300- and 400-level) courses must be unique to each program; in other words, no advanced course may be “double-counted” for the course work needed to fulfill either program’s minimal requirements. Should a student’s major and minor programs require the same course, a departmentally sanctioned elective must be chosen to replace the course in one of the programs.

### The Major with a Concentration in Biochemistry

Chemistry majors with a concentration in biochemistry should add Biol 2960 Principles of Biology I and Biol 2970 Principles of Biology II as prerequisites to the major and specify a minimum of 18 units in advanced courses in biology and chemistry, among which the following must be included:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chem 481</td>
<td>General Biochemistry I</td>
<td>3</td>
</tr>
<tr>
<td>Chem 482</td>
<td>General Biochemistry II</td>
<td>3</td>
</tr>
<tr>
<td>Chem 401</td>
<td>Physical Chemistry I</td>
<td>3</td>
</tr>
<tr>
<td>Chem 402</td>
<td>Physical Chemistry II</td>
<td>3</td>
</tr>
<tr>
<td>Chem 461</td>
<td>Inorganic Chemistry</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td><strong>Total Units</strong></td>
<td><strong>15</strong></td>
</tr>
</tbody>
</table>

In addition, at least one advanced lab must be chosen from the following list:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chem 358</td>
<td>Organic Chemistry Laboratory II</td>
<td>4</td>
</tr>
<tr>
<td>Chem 435</td>
<td>Nuclear and Radiochemistry Lab</td>
<td>3</td>
</tr>
<tr>
<td>Chem 445</td>
<td>Instrumental Methods: Physical Chemistry</td>
<td>3</td>
</tr>
<tr>
<td>Chem 470</td>
<td>Inorganic Chemistry Laboratory</td>
<td>3</td>
</tr>
<tr>
<td>Biol 437</td>
<td>Laboratory on DNA Manipulation</td>
<td>4</td>
</tr>
<tr>
<td>Biol 4522</td>
<td>Laboratory in Protein Analysis, Proteomics and Protein Structure</td>
<td>3</td>
</tr>
</tbody>
</table>

All chemistry course work must be taken in residence at Washington University to be applied toward the chemistry major. A minimum grade of C- must be earned in each course to count toward the chemistry major.

### Additional Information

#### Latin Honors for the Major in Chemistry:
To qualify for Latin Honors, students must complete a minimum of 21 units in advanced courses in chemistry or biochemistry, among which the following must be included:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chem 401</td>
<td>Physical Chemistry I</td>
<td>3</td>
</tr>
<tr>
<td>Chem 402</td>
<td>Physical Chemistry II</td>
<td>3</td>
</tr>
<tr>
<td>Chem 461</td>
<td>Inorganic Chemistry</td>
<td>3</td>
</tr>
</tbody>
</table>

The student must also take two additional advanced courses in chemistry.

Students must also complete **two** additional laboratories. Students must choose one synthetic laboratory:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chem 358</td>
<td>Organic Chemistry Laboratory II</td>
<td>4</td>
</tr>
<tr>
<td>Chem 470</td>
<td>Inorganic Chemistry Laboratory</td>
<td>3</td>
</tr>
</tbody>
</table>

and one physical laboratory:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chem 435</td>
<td>Nuclear and Radiochemistry Lab</td>
<td>3</td>
</tr>
<tr>
<td>Chem 445</td>
<td>Instrumental Methods: Physical Chemistry</td>
<td>3</td>
</tr>
</tbody>
</table>

Neither Chem 490 Introduction to Research nor Chem 495 Advanced Undergraduate Research in Chemistry can be used to satisfy the advanced laboratory requirements, but Chem 495 can be used to satisfy an elective.

#### Latin Honors for the Major in Chemistry with Concentration in Biochemistry:
To qualify for Latin Honors, students must complete a minimum of 21 units in advanced courses, including **either** one of the following five courses:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biol 334</td>
<td>Cell Biology</td>
<td>3</td>
</tr>
<tr>
<td>Biol 349</td>
<td>Microbiology</td>
<td>4</td>
</tr>
<tr>
<td>Chem 453</td>
<td>Bioorganic Chemistry</td>
<td>3</td>
</tr>
<tr>
<td>Chem 464</td>
<td>Inorganic Biochemistry</td>
<td>3</td>
</tr>
<tr>
<td>Chem 485</td>
<td>Nucleic Acids</td>
<td>3</td>
</tr>
</tbody>
</table>
or a second laboratory course in advanced chemistry or biology chosen from the following list:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chem 358</td>
<td>Organic Chemistry Laboratory II</td>
<td>4</td>
</tr>
<tr>
<td>Chem 435</td>
<td>Nuclear and Radiochemistry Lab</td>
<td>3</td>
</tr>
<tr>
<td>Chem 445</td>
<td>Instrumental Methods: Physical Chemistry</td>
<td>3</td>
</tr>
<tr>
<td>Chem 470</td>
<td>Inorganic Chemistry Laboratory</td>
<td>3</td>
</tr>
<tr>
<td>Biol 437</td>
<td>Laboratory on DNA Manipulation</td>
<td>4</td>
</tr>
<tr>
<td>Biol 4522</td>
<td>Laboratory in Protein Analysis, Proteomics and Protein Structure</td>
<td>3</td>
</tr>
<tr>
<td>Biol 4520</td>
<td>Protein Function in Model Cellular Systems</td>
<td>3</td>
</tr>
</tbody>
</table>

Departmental Honors for the Majors in Chemistry and Chemistry with a Concentration in Biochemistry: To graduate "with distinction," a student must maintain a Chemistry grade-point average of 3.5 and complete at least one semester of Chem 490 research. To graduate "with high distinction," a student must maintain a Chemistry GPA of 3.65 and complete at least two semesters of chemistry research, one of which must be Chem 495. To graduate "with highest distinction," a student must maintain a Chemistry GPA of 3.8 and complete at least two semesters of chemistry research, one of which must be Chem 495. Chemistry research is defined as a research project performed under the direction of a Chemistry faculty member or a research project approved by the Chemistry Department Undergraduate Work Committee. A Chemistry GPA is calculated from the grades received in chemistry courses and chemistry prerequisites. The level of Departmental Honors that a student achieves will appear on the student's final transcript.

**Minors**

**The Minor in Chemistry**

Units required: 27 in chemistry; 17 in math and physics

Required courses:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chem 111A</td>
<td>General Chemistry I</td>
<td>3</td>
</tr>
<tr>
<td>Chem 112A</td>
<td>General Chemistry II</td>
<td>3</td>
</tr>
<tr>
<td>Chem 151</td>
<td>General Chemistry Laboratory I</td>
<td>2</td>
</tr>
<tr>
<td>Chem 152</td>
<td>General Chemistry Laboratory II</td>
<td>2</td>
</tr>
<tr>
<td>Chem 261</td>
<td>Organic Chemistry I with Lab</td>
<td>4</td>
</tr>
<tr>
<td>Chem 262</td>
<td>Organic Chemistry II with Lab</td>
<td>4</td>
</tr>
<tr>
<td>Math 131</td>
<td>Calculus I</td>
<td>3</td>
</tr>
<tr>
<td>Math 132</td>
<td>Calculus II</td>
<td>3</td>
</tr>
<tr>
<td>Math 233</td>
<td>Calculus III</td>
<td>3</td>
</tr>
<tr>
<td>Physics 191</td>
<td>Physics I</td>
<td>3</td>
</tr>
<tr>
<td>Physics 191L</td>
<td>Physics I Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>Physics 192</td>
<td>Physics II</td>
<td>3</td>
</tr>
</tbody>
</table>

**Elective courses:**

Student must complete 9 units of chemistry encompassing three courses in at least two subdisciplines. Biol 451 General Biochemistry may be used to satisfy one course of the three required. Courses must be at the 300 level or above, but Chem 490 Introduction to Research is specifically excluded.

All chemistry course work must be taken in residence at Washington University to be applied toward the chemistry minor. A minimum grade of C- must be earned in each course to count toward the chemistry minor.

**Courses**


**L07 Chem 105 Introductory General Chemistry I**

This course traces the development of chemistry from early atomic theory to modern descriptions of structure, bonding, and intermolecular interactions. Over the course of the semester, the students learn how macroscopic observations of stoichiometry, chemical reactions, the properties of elements and compounds, and chemical periodicity developed into the microscopic understanding of molecular structure and bonding. The semester begins with fundamentals related to stoichiometry, chemical reactions, solution chemistry, and gas properties, with an emphasis on quantitative problem solving. The octet rule, Lewis structures, and valence-shell electron-pair repulsion (VSEPR) theory are then introduced as early efforts to describe the stability and structures of molecules. The localized electron model (LEM) and molecular-orbital theory (MOT) are next described as modern descriptions of chemical bonding. The course concludes with intermolecular forces such as hydrogen bonding and van der Waals interactions. This course will be a serious introductory series that requires and develops algebraic computation and problem-solving skills. Prerequisites: two years of high school math, one year of high school chemistry or physics, or permission of the instructor.

Credit 3 units. A&S IQ: NSM, AN BU: SCI
L07 Chem 106 Introductory General Chemistry II
This course covers chemical equilibrium, thermodynamics, and kinetics at a fundamental level, with an emphasis on in-class problem solving. Gas-phase reactions, heterogeneous (multi-phase) reactions, acid-base reactions, and solubility equilibria are introduced first. Chemical thermodynamics is then taught in its relation to chemical equilibrium. The course finishes with chemical kinetics and rate laws. The content is similar to that of Chem 112A, but advanced applications are omitted to allow for more in-class guided active learning. Prerequisites: two years of high-school math, one year of high-school chemistry or physics, and Chemistry 105 or 111A, or by permission of the instructors. Credit 3 units. A&S IQ: NSM, AN

L07 Chem 111A General Chemistry I
Systematic treatment of fundamental chemical principles and their applications. Particular reference to the concept of energy and its uses, gas laws, kinetic molecular theory, atomic and molecular structure, chemical bonding, and the periodic classification of the elements. Prerequisites: two years of high school algebra and one of high school chemistry, or permission of instructor. Credit 3 units. A&S IQ: NSM, AN Art: NSM BU: SCI

L07 Chem 112A General Chemistry II
Introduction to the principles of chemical equilibrium and to ionic solutions. Topics: ionic equilibria, galvanic cells, elementary chemical thermodinamics and kinetics, and molecular structure of coordination compounds. Three lecture hours and a problem-solving subsection hour. Sign-up for subsections is conducted during the first two weeks of the semester. Prerequisite: Chem 111A or permission of instructor. Credit 3 units. A&S IQ: NSM, AN Arch: NSM Art: NSM BU: SCI

L07 Chem 151 General Chemistry Laboratory I
This course provides an introduction into basic laboratory techniques, the experimental method, and the presentation of scientific data, as well as direct experience with chemical principles and the properties and reactions of substances. The course is designed to be taken concurrently with the first semester of the general chemistry lecture series (Chem 111A). Students attend a lab lecture every Monday and perform experiments during their scheduled lab section every week. Consult course listings for more information. Prerequisite: concurrent enrollment in Chem 111A or permission of the instructor. Credit 2 units. A&S IQ: NSM Art: NSM

L07 Chem 152 General Chemistry Laboratory II
This course provides an introduction to basic laboratory techniques, the experimental method, and the presentation of scientific data as well as direct experience with chemical principles and the properties and reactions of substances. The topics and experiments in this course complement the material covered in the Chem 112A lecture course. Students attend one four-hour laboratory session and one one-hour laboratory lecture every other week. Prerequisite: concurrent enrollment in Chem 112A or permission of the instructor. Credit 2 units. A&S IQ: NSM Arch: NSM Art: NSM

L07 Chem 151 General Chemistry Laboratory II
This course covers chemical equilibrium, thermodynamics, and kinetics at a fundamental level, with an emphasis on in-class problem solving. Gas-phase reactions, heterogeneous (multi-phase) reactions, acid-base reactions, and solubility equilibria are introduced first. Chemical thermodynamics is then taught in its relation to chemical equilibrium. The course finishes with chemical kinetics and rate laws. The content is similar to that of Chem 112A, but advanced applications are omitted to allow for more in-class guided active learning. Prerequisites: two years of high-school math, one year of high-school chemistry or physics, and Chemistry 105 or 111A, or by permission of the instructors. Credit 3 units. A&S IQ: NSM, AN

L07 Chem 152 General Chemistry Laboratory II
This course provides an introduction into basic laboratory techniques, the experimental method, and the presentation of scientific data, as well as direct experience with chemical principles and the properties and reactions of substances. The topics and experiments in this course complement the material covered in the Chem 112A lecture course. Students attend one four-hour laboratory session and one one-hour laboratory lecture every other week. Prerequisite: concurrent enrollment in Chem 112A or permission of the instructor. Credit 2 units. A&S IQ: NSM Arch: NSM Art: NSM

L07 Chem 181 First-Year Opportunity: Applications in Chemistry
This course involves a weekly lecture by a chemistry faculty member or by another scientist from academia or industry about their current research activities. The goal is to provide students with a sampling of current research activities dealing with fundamental and applied problems in science and society that are being approached from a chemical point of view. Students will see how fundamental chemical principles can be obtained from experiment and theory and used to both better understand and make better the world we live in. Each week, a different scientist presents a lecture or offers an additional activity. The course is intended primarily for freshman who anticipate majoring in science, but interested upperclass students should also find the lectures interesting and stimulating. Students are expected to attend all lectures and associated activities during the semester. Credit/no credit only. Course is for first-year, non-transfer students only. Credit 1 unit. A&S: FYO A&S IQ: NSM Art: NSM

L07 Chem 182 Chemistry for Concerned Citizens: Topics in Energy, the Environment, and More
This course is designed to provide an overview of chemistry as it relates to problems in environmental science, energy and related topics. It is constructed such that all students, irrespective of their major area of study, can learn about chemistry in these contexts. The course is intended to be highly interdisciplinary; therefore, it covers subjects including chemistry, physics, engineering, geology, biology, environmental policy and others. Credit 3 units. A&S IQ: NSM, AN Arch: NSM Art: NSM

L07 Chem 261 Organic Chemistry I with Lab
The first part of a two-semester survey of organic chemistry. The course includes an introduction to organic structures, reactions and reaction mechanisms. The laboratory meets on alternate weeks and include an introduction to laboratory methods in organic chemistry, including separation and methods of purification of organic compounds. Prerequisites: Chem 112A, Chem 152. Credit 4 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L07 Chem 262 Organic Chemistry II with Lab
A course covering certain areas of organic chemistry in more detail than the prerequisite course, with special emphasis on the mechanisms and the synthetic applications of organic reactions and on the organic chemistry of biological compounds. The laboratory meets eight times and includes organic synthesis and spectroscopic techniques. Required course for chemistry majors. Prerequisite: Chem 261. Credit 4 units. A&S IQ: NSM Arch: NSM Art: NSM

L07 Chem 290 First-Year and Sophomore Research
Introduction to laboratory research for first- and second-year students. Students work under supervision of a faculty sponsor. Prerequisite: permission of the sponsor and the Department of Chemistry. Credit/no credit only. Credit variable, maximum 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L07 Chem 299 Chemical Laboratory Safety
An overview of current laboratory safety, regulatory and compliance practices. Safety and compliance issues that impact
chemical, biological and materials research is covered through a series of lectures, demonstrations, activities and laboratory exercises. Credit 0.5 units. A&S IQ: NSM; BU: SCI

L07 Chem 358 Organic Chemistry Laboratory II
Initially, problem solving in organic chemistry is emphasized through an introduction to the methods of qualitative organic analysis, including the use of chromatographic and spectroscopic techniques. Each student then selects an independent synthetic project to perform. Prerequisite: Chem 262. Six laboratory hours per week. Lectures held three hours a week for the first half of the semester. Credit 4 units. A&S IQ: NSM; WI; Art: NSM

L07 Chem 400 Physical Science in 12 Problems
Exercises related to general chemistry, classical mechanics, quantum mechanics, statistical mechanics, thermodynamics and kinetics, are solved with numerical software. Each exercise is accompanied by a lecture, a software template solving a problem and a related take-home problem. The software allows us to focus on, and treat in a transparent fashion, physical problems without the unworthy idealizations and contrivances found in textbooks. Prerequisites: Chem 111A Chemistry I, concurrent enrollment with Chem 401 and prior or concurrent enrollment in Physics 117A Physics I. Credit 1 unit. A&S IQ: NSM; Art: NSM

L07 Chem 401 Physical Chemistry I
Introduction to quantum chemistry (with applications to elementary spectroscopy) and kinetics. Prerequisites: Chem 111A–Chem 112A, Math 233; prior completion of Physics 117A and Physics 118A is strongly encouraged (but concurrent enrollment in Physics 117A is accepted); or permission of instructor. Required course for all Chemistry majors. Credit 3 units. A&S IQ: NSM; Art: NSM; BU: SCI

L07 Chem 402 Physical Chemistry II
Introduction to chemical thermodynamics, statistical mechanics and transport phenomena. Required course for all Chemistry majors. Prerequisites: Chem 111A–Chem 112A, Chem 401, Math 233; prior completion of Physics 117 and 118 is strongly encouraged (but prior completion of Physics 117 and concurrent enrollment in Physics 118 are accepted); or permission of instructor. Credit 3 units. A&S IQ: NSM; Art: NSM; BU: SCI

L07 Chem 403 Chemical Kinetics
This lecture course provide an introduction to the kinetics of chemical reactions for graduate and upper-level undergraduate science and engineering students. Bulk and molecular level considerations are discussed and provide a foundation for the understanding of chemical reaction mechanisms and the techniques used for their study. Students gain an understanding of the importance and significance of the rate laws of reactions and in particular the reaction rate constant. Details of how the environment in which reactions occur (e.g., gas phase, solution phase and surface reactions) and molecular structure are reflected in the rate constant are discussed. Examples such as catalytic loss cycles in the atmosphere, enzyme catalysis, combustion systems, chain reactions and explosions are presented in detail to illustrate how the fundamental principles of chemical kinetics can be applied to predict reaction rates, chemical reactivity and the outcomes of particular processes. Credit 3 units. A&S IQ: NSM; Arch: NSM; Art: NSM

L07 Chem 426 Inorganic Electrochemistry and Photochemistry
An understanding of electrochemical processes is critical in describing the behavior of batteries, photovoltaics, solar fuel systems, and other important devices used in energy conversion and environmental remediation. This course will cover modern inorganic electrochemistry, photochemistry, and photoelectrochemistry from a microscopic perspective of solid-electrolyte interfaces. The course material will start with the thermodynamics of solid-electrolyte interfaces and the kinetics of electron transfer across these interfaces. Electroanalytical techniques, such as cyclic voltammetry and potential step methods, will be described to understand the mechanism of various electrochemical and photochemical reactions. The second half of the course will cover several applications of electrochemical cells, including batteries, fuel cells, and photoelectrochemical cells. Prerequisites: Chem 461 or Chem 465 or consent of instructor. Credit 3 units. A&S IQ: NSM; Arch: NSM

L07 Chem 430 Simulation in Chemistry and Biochemistry
This course explores a wide range molecular modeling techniques and applications of computational chemistry to problems in chemistry and biochemistry. Topics include ab initio quantum mechanics, semi-empirical MO theory, molecular mechanics, molecular dynamics simulation, coarse-grained models, electrostatic methods and biomolecular structure prediction. A major component of the course is weekly laboratory sessions using common software programs in the field, including Spartan, Q-Chem, Gaussian, VMD, TINKER, APBS, AutoDock, SDA7 and others. Many of the lab exercises target proteins, nucleic acids and other biomolecular structures. As a final lab experience, students complete an independent project using tools covered in the course. Credit 3 units. A&S IQ: NSM; Arch: NSM

L07 Chem 435 Nuclear and Radiochemistry Lab
Application of radiochemical techniques to problems in chemistry, physics and nuclear medicine. Prerequisites: 3 units of physical chemistry and permission of instructor. One lecture hour and five hours of laboratory a week. Credit 3 units. A&S IQ: NSM; Arch: NSM

L07 Chem 436 Radioactivity and Its Applications
Introduction to the production and decay of radioactive nuclides, the structure and properties of nuclei, and the applications of nuclear and radiochemical techniques to current scientific problems. Prerequisites: one year each of chemistry, mathematics and physics. Credit 3 units. A&S IQ: NSM; Arch: NSM

L07 Chem 437 Radioactivity and Radiation Safety
The following topics are discussed: (a) general properties of nuclei; (b) laws of radioactive decay; (c) interaction of radiation with matter; (d) radiation detectors; (e) radiation dosimetry; (f) biological effects of radiation exposure; (g) radiation safety, safety test, regulations; (h) basics of radioisotope production. Credit 1 unit. A&S IQ: NSM; Arch: NSM
L07 Chem 445 Instrumental Methods: Physical Chemistry
A course providing direct hands-on experience with the principles of physical chemistry (thermodynamics, quantum, kinetics) and associated experimental methods and instrumentation, including optical, infrared, and nuclear and electron spin resonance, electrochemistry, calorimetry, laser kinetics, and basic electronics. Prerequisite: Chem 401 or concurrent enrollment in Chem 402. Credit 3 units. A&S IQ: NSM, WI Arch: NSM Art: NSM

L07 Chem 450 Mechanistic Organic Chemistry
The first half of a sequence of two seminars, followed by Chem 554 in the spring, encompassing important topics in physical organic chemistry. The first semester is devoted to the fundamental concepts of mechanistic organic chemistry. The major classes of organic reactions are surveyed from a mechanistic perspective. Prerequisite: Chem 262 or permission of the instructor. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L07 Chem 451 Organic Chemistry III
A lecture course that builds on the material in Chem 261 and Chem 262, covering in more detail certain topics in those courses while also introducing new topics. A transition to graduate-level study in organic chemistry; recommended for chemistry, biochemistry and biology majors. Prerequisite: Chem 262. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L07 Chem 453 Bioorganic Chemistry
The focus of this course in an overview of modern medicinal chemistry from the selection of a therapeutic target through the FDA-approval process. Each aspect is exemplified by examples of drugs currently in clinical use or in late-stage development. One aspect of particular interest to synthetic chemists is the underlying development chemistry that often determines the competitive success of a product. Topics covered include peptidomimetic HIV protease inhibitors, topoisomerase inhibitors, HMGG-CoA-reductase inhibitors (Lipitor, etc.), receptor tyrosine-kinase inhibitors (Gleevec, etc.), a synthetic mimetic of superoxide dismutase, and several others depending on the interests of the participants. Students are responsible for presenting to the class the synthetic routes developed for the discovery and commercialization of these drugs focusing on development chemistry. Prerequisite: Chem 262. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L07 Chem 458 Chemical Reaction Mechanism Journal Club
This seminar meets for one hour each week. During the meetings, student participants are responsible for presenting topics from the current literature. The format of the presentation varies from informal talks to student-authored problem sets. Attendance at meetings is strongly recommended for all students who are currently taking the organic cumulative examinations. Prerequisite: Chem 262. Credit 1 unit. A&S IQ: NSM Arch: NSM Art: NSM

L07 Chem 459 Organometallic Chemistry
Survey of organometallic compounds with discussion of their synthesis, structure, spectroscopy and reactivity. Prerequisite: Chem 252. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L07 Chem 461 Inorganic Chemistry
Introduction to modern inorganic chemistry; emphasis on relation of structure and bonding to the chemical and physical properties of compounds. Prerequisite: Chem 401 or permission of instructor. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L07 Chem 464 Inorganic Biochemistry
A class in biological chemistry that emphasizes the role of metals in electron transfer and enzymatic catalysis. After a brief survey of essential concepts from biology, coordination chemistry and spectroscopy, topics include: electron transfer systems; oxygen transport and activation; metal ion acquisition, transport and homeostasis; enzymes catalyzing atom transfer reactions and radical-mediated processes. Prerequisites: Chem 252; Chem 461 recommended but not required. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L07 Chem 465 Solid-State and Materials Chemistry
The course begins with basic crystallography and common inorganic structure types. With the aid of computer modeling, students learn to analyze, index and refine X-ray powder-diffraction data. Students are then taught to use phase diagrams to assess the compositions and microstructures of materials produced by various synthetic or processing methods. Crystal nucleation and growth, defects, and ion-conduction mechanisms also are introduced. The course concludes with an analysis of the mechanical properties of materials from a chemistry perspective. What makes some materials strong, stiff and resistant to fracture? Prerequisites: Chem 111A-Chem 112A. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L07 Chem 470 Inorganic Chemistry Laboratory
A laboratory course emphasizing both the synthesis of inorganic compounds and the study of their physical properties. Laboratory exercises will introduce novel synthetic techniques such as high-temperature synthesis and vacuum line manipulations. Compounds will be spectroscopically characterized by UV-visible, gas-phase infrared, and multinuclear and dynamic NMR spectroscopy. Measurements of electrochemical behavior, magnetic susceptibility, and electrical conductivity will be performed. Prerequisite: Chem 461 or consent of the instructor. A Writing Intensive option is available with the permission of the instructor. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L07 Chem 470W Inorganic Chemistry Laboratory — Writing Intensive
A laboratory course emphasizing both the synthesis of inorganic compounds and the study of their physical properties. Laboratory exercises introduce novel synthetic techniques such as high-temperature synthesis and vacuum line manipulations. Compounds are spectroscopically characterized by UV-visible, gas-phase infrared, and multinuclear and dynamic NMR spectroscopy. Measurements of electrochemical behavior, magnetic susceptibility and electrical conductivity are performed. Prerequisite: Chem 461 or consent of the instructor. This course satisfies the writing-intensive requirement. Credit 3 units. A&S IQ: NSM, WI Arch: NSM Art: NSM

L07 Chem 475 Chemical Biology
This course is a survey of modern chemical biology focusing on the application of a broad array of chemical tools to biological
problems. The course is roughly divided into four sections; biopolymers, computational methods and bioinformatics; tools for chemical biology; and applications of chemical biology. A mandatory discussion section accompanies the course and is used to review current and classical literature in the field. Prerequisites: Chem 262 and Biol 2970, or permission of the instructor. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

**L07 Chem 479 Computational Chemistry and Molecular Modeling**

Lectures cover the background, practice and applications of computational chemistry to the modeling of the structures and chemical reactions of organic molecules. Different levels of calculation are presented, from molecular mechanics calculations and Hückel molecular orbital theory, through semi-empirical and ab initio self-consistent field calculations with correlation energy corrections, and density functional theory. Hands-on experience performing calculations is an important element in this course.

Credit 3 units. A&S IQ: NSM, WI Arch: NSM Art: NSM

**L07 Chem 481 General Biochemistry I**

Topics include the properties and structures of biomolecules, including amino acids, nucleotides, lipids, carbohydrates, proteins and nucleic acids. Additional topics include enzyme kinetics and mechanisms, membrane structure and properties, protein folding, an introduction to metabolism, oxidative phosphorylation, and photosynthesis. This course is the first semester of an integrated two-semester sequence. The second course is Chem 482. Prerequisites: Biol 2970, Chem 262. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

**L07 Chem 482 General Biochemistry II**

Continuation of General Biochemistry I. Topics include carbohydrate, lipid and amino acid metabolism, signal transduction, transport across membranes, DNA replication and repair, transcription and translation, molecular motors, mechanisms of drug action and natural products biosynthesis. Prerequisite: Chem 481 or Biol 481. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

**L07 Chem 483 Protein Biochemistry**

The focus of this course is protein biochemistry, and is intended to build upon General Biochemistry (Chem 481). In this course we will focus on protein structure, folding, and techniques to purify and characterize protein activity. We will progress from initial studies to first understand protein fold and function to current efforts to better characterize protein structure-function relationships. We will also highlight human diseases that are underpinned by protein misfolding. This course will focus on reading and understanding primary literature, including landmark papers along with more recent work. During the second half of the semester, each student will select a paper and prepare a written analysis of that paper. The student will then present the paper and lead a journal club style discussion of the paper.

Prerequisites: Chem 481 or instructor's permission. Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

**L07 Chem 485 Nucleic Acids**

Structure, synthesis, properties, and interactions of nucleic acids, and the design and synthesis of nucleic acid-based and/or targeted drugs, probes and tools. Topics: primary, secondary and tertiary structure; topological and thermodynamic properties; biological and chemical synthesis; DNA chips; PCR; site-directed natural and unnatural mutagenesis; chemical evolution (SELEX); ribozymes; phage display; carcinogen, drug and protein interactions; affinity cleaving; ultraviolet light and ionizing radiation damage, DNA repair of mutagenesis; design and synthesis of anti-sense and anti-gene probes and drugs. Extensive use is also made of molecular modeling and the protein databank of nucleic acid structures. Prerequisites: Chem 251 and Chem 252 or equivalent.

Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

**L07 Chem 488 Modern Spectroscopy**

This course focuses on the fundamental principles and methodologies associated with numerous optical spectroscopy techniques that are commonly utilized in physical and life sciences research laboratories. In order to develop a solid understanding of the material as well as best practices, and the strengths and limitations of the techniques, this course combines lectures with laboratory experiments. Students also learn how to analyze and interpret data and succinctly describe their results. During one lecture each week the underlying principles of a specific type of spectroscopy are presented. The second lecture each week is spent covering the general details of the instrumentation and methods for acquiring spectra on different types of samples. The students then acquire spectra using the spectroscopic methods presented during the laboratory session. The students independently analyze the data and write brief reports of their findings. During the last two weeks of class, pairs of students are given an unknown, and they need to identify and characterize the sample and then write and submit a final report describing this independent research and their findings.

Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

**L07 Chem 490 Introduction to Research**

Advanced laboratory work on a selected topic in chemistry. Prerequisite: permission of the department. Credit/no credit only. If this course is to be submitted for Honors, the student must file the Honors form available at the chemistry department office before the end of junior year. Arrangements for registration should be completed during the preregistration period.

Credit variable, maximum 6 units. A&S IQ: NSM Art: NSM

**L07 Chem 495 Advanced Undergraduate Research in Chemistry**

The student conducts research supervised by a chemistry department faculty member. At the end of the semester, the chemistry supervisor chairs a faculty committee to evaluate an oral public presentation and/or a concise written report, and a letter grade is assigned. The committee members and completion requirements must be approved by the supervisor prior to registration. This course may provide a Capstone Experience but does not fulfill the Writing-Intensive requirement. The units earned may be applied as elective advanced credits toward a chemistry major with Latin honors eligibility. Course may be taken only once for credit. Prerequisite: Chem 490 and/or other advanced electives or research experience specified by the supervisor.

Credit 3 units. A&S IQ: NSM Art: NSM