Chemistry

Chair
Lai-Sheng Wang

The Department of Chemistry maintains pedagogical and research strengths in organic, inorganic, theoretical and experimental physical chemistry, analytical chemistry, chemical biology and nanotechnology. Faculty, post-doctoral fellows, graduate and undergraduate students collaboratively pursue interdisciplinary research within the department, enhanced by the partnerships with colleagues in the medicine, biology, geology, physics and engineering.

For additional information, please visit the department's website: http://www.brown.edu/academics/chemistry/

Chemistry Concentration Requirements

The Chemistry concentration offers courses and research opportunities that range from fundamental studies involving the characterization and preparation of synthetic and naturally occurring molecules, to interdisciplinary studies at the interfaces of chemistry with biology, medicine, physics, engineering, and nanoscience. As early as their first year, undergraduates are able to work one-on-one or in small groups with faculty members on cutting edge research projects. The Sc.B. degree provides a thorough foundation for further graduate study or for entry-level technical positions in each area. Students seeking the Sc.B. may either pursue the standard Chemistry concentration or one of the two optional tracks: Chemical Biology or Materials Chemistry. Students may also pursue the A.B. degree in Chemistry, which provides a core education in the discipline.

Standard program for the A.B. degree

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 0330</td>
<td>Equilibrium, Rate, and Structure</td>
<td>1</td>
</tr>
<tr>
<td>CHEM 0350</td>
<td>Organic Chemistry</td>
<td>1</td>
</tr>
<tr>
<td>CHEM 0360</td>
<td>Organic Chemistry</td>
<td>1</td>
</tr>
<tr>
<td>CHEM 0500</td>
<td>Inorganic Chemistry</td>
<td>1</td>
</tr>
<tr>
<td>CHEM 1140</td>
<td>Physical Chemistry: Quantum Chemistry 1</td>
<td>1</td>
</tr>
<tr>
<td>CHEM 1150</td>
<td>Physical Chemistry: Thermodynamics and Statistical Mechanics 1</td>
<td>1</td>
</tr>
<tr>
<td>CHEM 1160</td>
<td>Physical Chemistry Laboratory</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Two advanced science/math electives.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Total Credits</td>
<td>9</td>
</tr>
</tbody>
</table>

1. Note that the physical chemistry courses (CHEM 1140, CHEM 1150, CHEM 1160) have mathematics and physics prerequisites.
2. At least one must be a chemistry course. BIOL 0280 is credited as a chemistry elective for chemistry concentration purposes. Non-CHEM electives are upper level science/math courses with a significant molecular focus or those that cover tools/techniques that are of utility to a chemist. You should discuss your elective choices with the Concentration Advisor to craft a course of study that is appropriate for your interests.

Standard program for the Sc.B. degree

The Chemistry Department offers three tracks for the Sc.B. Chemistry Concentration — a Chemistry track, a Chemical Biology track and a Materials Chemistry track. These tracks are not separate concentrations — your degree will still be an Sc.B. in Chemistry. The Chemical Biology track is designed for students who have a strong interest in the interface of chemistry with biology. The Materials Chemistry track is designed for students who have a strong interest in the interface of chemistry with nanoscience and materials science. The expectation is that courses required for the concentration will be taken for a letter grade.

Concentrating in Chemistry – Three tracks

The required/recommended courses for the three tracks are given below.
1 BIOL 0280 is credited as a chemistry elective for the chemistry concentration. Non CHEM electives are upper level science/math courses with a significant molecular focus or those that cover tools/techniques that are of utility to a chemist. You should discuss your elective choices with the Concentration Advisor to craft a course of study that is appropriate for your interests.

2 For students with a more Engineering bent, the following substitutions can be made: ENGN 0030/ENGN 0040 can be substituted for PHYS; ENGN 0410 can be substituted for CHEM 1060; ENGN 0720 for CHEM 1150.

3 NOTE: MATH 0180 has additional prerequisites.

4 NOTE: Many of the BIOL courses have BIOL 0200 as a prerequisite.

In each of these cases, CHEM 0970/CHEM 0980 should be carried out with a faculty member with an appointment in the Chemistry Department. Research with faculty advisors outside Chemistry may be allowed in some special cases. In this event, the student should a) prepare a proposal for the research to be carried out and b) identify a faculty member in the Chemistry Department who will serve as a second advisor and the second reader for the thesis.

Honors Requirements for Chemistry
All ScB Chemistry concentrators, and any AB concentrator who completes the following requirements, are candidates for Honors; no separate application is necessary. The requirements for Honors in Chemistry are:

* A strong grade record in concentration courses. This means a grade point average for the concentration that is higher than 3.50.

* Two semesters of Independent Study (CHEM 0970, CHEM 0980 or equivalent). Guidelines and requirements associated with Independent Study are in the Undergraduate Concentration Handbook which can be found at the department website (http://www.brown.edu/academics/chemistry/undergraduate).

* A Thesis in a form approved by the research advisor, and recommended by the research advisor. Additional information about thesis guidelines will be provided by the Concentration Advisor in the first half of the fall semester.

* A Poster presentation at the chemistry department’s spring undergraduate poster session.

Biochemistry & Molecular Biology Concentration Requirements
How does life work at the molecular level? This question is at the core of the concentration program Biochemistry and Molecular Biology. In earlier years of this discipline, the focus was on structure and function of proteins, nucleic acids, lipids, carbohydrates and small molecules such as vitamins. Today the logical approach and tools of biochemical science are being expanded to new areas in neuroscience, developmental biology, immunology, pharmacology and synthetic biology (the design of analogs of biological systems). Training in biochemistry begins with a foundation in mathematics, physics, chemistry and biology. Some courses offered in other departments, including engineering, geology and computer science, are also useful. A key component of this program is the year of hands-on research carried out in collaboration with a faculty member here at Brown. Faculty sponsors are drawn from both the Chemistry Department and the Division of Biology and Medicine, and include basic science and clinical faculty.

Standard program for the Sc.B. degree
Students must take twenty courses in biology, chemistry, mathematics, and physics, including the following core requirements, some of these may be fulfilled with AP credits. Students are expected to take courses that will count toward the concentration ABC/NC. Students should discuss the S/NC option with their concentration advisor if circumstances warrant consideration. Students should not register S/NC for a concentration course without advisor pre-approval.

Three courses in mathematics, statistics and/or computer science, typically including MATH 0090, MATH 0100, or equivalent): 1

Two courses in physics, typically: 1

PHYS 0030  Basic Physics A
or PHYS 0050  Foundations of Mechanics
or ENGN 0030  Introduction to Engineering

PHYS 0040  Basic Physics B
or PHYS 0060  Foundations of Electromagnetism and Modern Physics
or ENGN 0040  Dynamics and Vibrations

Three courses in physical and organic chemistry:

CHEM 0330  Equilibrium, Rate, and Structure
CHEM 0350/0360  Organic Chemistry

One course in biophysical or related chemistry:

CHEM 0500  Inorganic Chemistry

-or-

GEOL 1660  Instrumental Analysis with Environmental Applications

Four courses in biochemistry: 2

BIOL 0280  Biochemistry
BIOL 0285  Inquiry in Biochemistry: From Gene to Protein Function

Plus two of the three upper level biochemistry courses:

BIOL 1270  Advanced Biochemistry
or CHEM 1230  Chemical Biology
or CHEM 1240  Biochemistry

Select two semester courses of independent research approved by a concentration advisor:

BIOL 1950/1960  Directed Research/Independent Study

-or-

CHEM 0970/0980  Undergraduate Research

Suggested Elective Courses:
Students are required to take five courses from the chart below or, with approval from a concentration advisor, from any science or mathematics course relevant to biochemistry, cell and molecular biology. 3

Biology Electives:

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<thead>
<tr>
<th>Course</th>
<th>Title</th>
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<tbody>
<tr>
<td>BIOL 0200</td>
<td>The Foundation of Living Systems</td>
</tr>
<tr>
<td>BIOL 0380</td>
<td>The Ecology and Evolution of Infectious Disease</td>
</tr>
<tr>
<td>BIOL 0415</td>
<td>Microbes in the Environment</td>
</tr>
<tr>
<td>BIOL 0470</td>
<td>Genetics</td>
</tr>
<tr>
<td>BIOL 0500</td>
<td>Cell and Molecular Biology</td>
</tr>
<tr>
<td>BIOL 0530</td>
<td>Principles of Immunology</td>
</tr>
<tr>
<td>BIOL 0800</td>
<td>Principles of Physiology</td>
</tr>
<tr>
<td>BIOL 1050</td>
<td>Biology of the Eukaryotic Cell</td>
</tr>
<tr>
<td>BIOL 1090</td>
<td>Polymer Science for Biomaterials</td>
</tr>
<tr>
<td>BIOL 1100</td>
<td>Cell Physiology and Biophysics</td>
</tr>
<tr>
<td>BIOL 1110</td>
<td>Topics in Signal Transduction</td>
</tr>
<tr>
<td>BIOL 1200</td>
<td>Protein Biophysics and Structure</td>
</tr>
<tr>
<td>BIOL 1210</td>
<td>Synthetic Biological Systems</td>
</tr>
<tr>
<td>BIOL 1260</td>
<td>Physiological Pharmacology</td>
</tr>
<tr>
<td>BIOL 1290</td>
<td>Cancer Biology</td>
</tr>
<tr>
<td>BIOL 1310</td>
<td>Developmental Biology</td>
</tr>
<tr>
<td>BIOL 1330</td>
<td>Biology of Reproduction</td>
</tr>
<tr>
<td>BIOL 1520</td>
<td>Innate Immunity</td>
</tr>
<tr>
<td>BIOL 1540</td>
<td>Molecular Genetics</td>
</tr>
<tr>
<td>BIOL 1560</td>
<td>Virology</td>
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</tbody>
</table>
BIOL 1600  Development of Vaccines to Infectious Diseases
BIOL 2110  Drug and Gene Delivery

**Neuroscience Electives:**
- NEUR 0010  The Brain: An Introduction to Neuroscience
- NEUR 0650  Biology of Hearing
- NEUR 1020  Principles of Neurobiology
- NEUR 1040  Introduction to Neurogenetics
- NEUR 1670  Neuropharmacology and Synaptic Transmission

**Chemistry Electives:**
- CHEM 0500  Inorganic Chemistry
- CHEM 1140  Physical Chemistry: Quantum Chemistry
- CHEM 1150  Physical Chemistry: Thermodynamics and Statistical Mechanics
- CHEM 1220  Computational Tools in Biochemistry and Chemical Biology
- CHEM 1230  Chemical Biology
- CHEM 1240  Biochemistry
- CHEM 1450  Advanced Organic Chemistry

**Computer Science Electives:**
- CSCI 1810  Computational Molecular Biology

**Total Credits:** 20

1. Note that the mathematics and physics requirements may be satisfied by Advanced Placement credit.
2. BIOL 0285 is required for the class of 2022 onward. Students in the classes of 2019-2021 are required to take only three courses in biochemistry yet may take BIOL 0285 as an elective.
3. Students in the classes of 2019-2021 are required to take six electives. The five elective requirement applies to the class of 2022 and after.
4. or any NEUR course in Cell, Genetics, Molecular Biology, or Development.

**Honors Requirements for Biochemistry**
All ScB Biochemistry concentrators are candidates for Honors; no separate application is necessary.

The requirements for Honors in Biochemistry are:
* A strong grade record in concentration courses. This means a grade point average for the concentration that is higher than 3.25.
* Two semesters of Independent Study (CHEM 0970, CHEM 0980 or equivalent). Guidelines and requirements associated with Independent Study are in the Undergraduate Concentration Handbook which can be found at the department website (http://www.brown.edu/academics/chemistry/undergraduate).
* A Thesis in a form approved by the research advisor, and recommended by the research advisor. Additional information about thesis guidelines will be provided by the Concentration Advisor in the first half of the fall semester.

**Chemical Physics Concentration Requirements**
Chemical Physics is an interdisciplinary field at the crossroads of chemistry and physics and is administered jointly by the two departments. The concentration provides students with a broad-based understanding in fundamental molecular sciences, as well as a background for graduate studies in physical chemistry, chemical physics, or molecular engineering. Concentrators are required to take twenty courses in chemistry, physics, and mathematics, although approved courses in applied mathematics, biology, computer science, geological sciences, or engineering may be substitutes. Chemical Physics concentrators are also advised to take at least six courses in the humanities and social sciences. Chemical Physics concentrators at all levels (first-year through seniors) are actively involved in research with faculty members in both departments.

**Standard program for the Sc.B. degree**
Twenty-one semester courses in chemistry, physics, and mathematics, with a minimum of four semester courses in mathematics. The expectation is that courses required for a concentration in Chemical Physics will be taken for a letter grade. Core courses are:
- CHEM 0330  Equilibrium, Rate, and Structure
- CHEM 0350  Organic Chemistry
- CHEM 0500  Inorganic Chemistry
- CHEM 1140  Physical Chemistry: Quantum Chemistry
- PHYS 0070  Analytical Mechanics
- PHYS 0160  Introduction to Relativity, Waves and Quantum Physics
- PHYS 0470  Electricity and Magnetism

Select one of the following laboratory courses:
- CHEM 1160  Physical Chemistry Laboratory
- PHYS 0560  Experiments in Modern Physics
- PHYS 1560  Modern Physics Laboratory

Select one course in statistical mechanics:
- CHEM 1150  Physical Chemistry: Thermodynamics and Statistical Mechanics
- PHYS 1530  Thermodynamics and Statistical Mechanics

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<thead>
<tr>
<th>Course</th>
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<th>Credits</th>
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<tbody>
<tr>
<td>MATH 0190</td>
<td>Advanced Placement Calculus (Physics/Engineering)</td>
<td>1</td>
</tr>
<tr>
<td>MATH 0200</td>
<td>Intermediate Calculus (Physics/Engineering)</td>
<td>1</td>
</tr>
<tr>
<td>MATH 0520</td>
<td>Linear Algebra</td>
<td>1</td>
</tr>
<tr>
<td>PHYS 0970/0980</td>
<td>Senior Conference Course</td>
<td>2</td>
</tr>
<tr>
<td>PHYS 1990</td>
<td>Undergraduate Research</td>
<td>1</td>
</tr>
</tbody>
</table>

**Honors Requirements for Chemical Physics**
All ScB Chemical Physics concentrators who complete the following requirements are candidates for Honors; no separate application is necessary.

The requirements for Honors in Chemical Physics are:
* A strong grade record in concentration courses. This means a grade point average for the concentration that is higher than 3.50.
* Two semesters of Independent Study (CHEM 0970, CHEM 0980, PHYS 1990 or equivalent). Guidelines and requirements associated with Independent Study are in the Undergraduate Concentration Handbook which can be found at the department website (http://www.brown.edu/academics/chemistry/undergraduate).
* A Thesis in a form approved by the research advisor, and recommended by the research advisor. Additional information about thesis guidelines will be provided by the Concentration Advisor in the first half of the fall semester.
* A Poster presentation at the chemistry department's spring undergraduate poster session.
Chemistry Graduate Program

The Department of Chemistry offers graduate programs leading to the Master of Arts (A.M.); the Master of Science (Sc.M.); and the Doctor of Philosophy (Ph.D.) degree.

Research in Chemistry stretches from the exploration of physical phenomena of individual molecules, to the creation of new molecules, to material science, and indeed to the foundations of life. The Department of Chemistry reflects this profound importance and diversity by offering excellent research opportunities in areas including organic and inorganic chemistry, chemical biology, analytical chemistry, nanochemistry and theoretical and experimental physical chemistry. In addition, graduate students have the opportunity to participate in interdisciplinary research in molecular biology, chemical engineering and the Institute for Molecular and Nanoscale Innovation. The faculty-student ratio is approximately 3:1 with most research groups numbering no more than six graduate students.

For more information on admission and program requirements, please visit the following websites:
http://www.brown.edu/academics/gradschool/programs/chemistry

Courses

CHEM 0080E. Exploration of the Chemistry of Renewable Energy. The various types of renewable energy sources will be explored through classroom discussions, activities, and laboratories. Students will learn about the various types of renewable energy sources and the chemistry associated with each. The course will include short laboratories to illustrate the application of the energy sources. Renewable energy will be discussed in relationship to environmental factors and social impact. Active learning strategies will be used throughout the course. For students of all disciplines who are interested in obtaining an understanding of renewable energy.

CHEM 0080A. First Year Seminar- Energy. A Freshman seminar that provides a survey of past and current concepts of three dimensional structures of molecules. The course will include short laboratories to illustrate the application of the energy sources. Renewable energy will be discussed in relationship to environmental factors and social impact. Active learning strategies will be used throughout the course. For students of all disciplines who are interested in obtaining an understanding of renewable energy.

CHEM 0080B. Molecular Structures in Chemistry and Biology. This course will consist of a survey of historical developments and concepts of three dimensional structures of molecules. The course will conclude with a survey of the current state of the art of structure determination and 3D structure motifs for small molecules, nanomaterials and biological macromolecules. This freshman only seminar will be strictly limited to a maximum of 19 students.

CHEM 0080C. Drug Discoveries in the Pharmaceutical Industry. A Freshman seminar that provides a survey of past and current approaches that enable the discovery and development of therapeutic agents. Topics ranging from target validation to the development of therapeutics (small molecules, biologics, and stem cells) will be discussed. Enrollment limited to 19 first-year students.

CHEM 0080D. Chemical Ecology: Pheromones, Poisons, and Chemical Messages. This first year seminar will explore how plants and animals use chemicals to send and receive information about mating, identify potential hosts, defend themselves, and establish social networks. We will focus on the chemistry and biochemistry of these signals, with some examples of the behavioral and ecological consequences of chemical signaling. Enrollment limited to 19 first year students.

CHEM 0080E. Exploration of the Chemistry of Renewable Energy. The various types of renewable energy sources will be explored through classroom discussions, activities, and laboratories. Students will learn about the various types of renewable energy sources and the chemistry associated with each. The course will include short laboratories to illustrate the application of the energy sources. Renewable energy will be discussed in relationship to environmental factors and social impact. Active learning strategies will be used throughout the course. For students of all disciplines who are interested in obtaining an understanding of renewable energy.

CHEM 0080F. Kitchen Chemistry. Have you ever wondered why olive oil is a liquid but butter is solid? Or why bread and cookies rise when baked? This Kitchen Chemistry course is an experimental approach to chemistry, as seen in cooking. We will examine topics such as trans fats, baking soda as a leavening agent in baking, ripening of fruit, artificial sweeteners, GMOs, and enzymatic and non-enzymatic browning of foods. Edible experiments will be used to discuss the science behind recipes. Enrollment limited to 14 first year students. Instructor permission is required.

CHEM 0090. Kitchen Chemistry. Kitchen Chemistry is a course that highlights the chemistry underlying food and cooking. We will examine topics such as trans fats, baking soda as a leavening agent in baking, chemical basis for ripening of fruit, pectin as a cellular glue, artificial sweeteners, GMOs, and enzymatic and non-enzymatic browning of foods. In-class demonstrations and edible experiments will be used to discuss the science behind cooking. Content will be discussed using a variety of contexts including primary scientific literature, public policy reports, mainstream media, and food blogs. This class is appropriate for all students interested in chemistry.

CHEM 0100. Introductory Chemistry. Explores stoichiometry, atomic and molecular structure, chemical bonding, solutions, gases, chemical reactions, equilibria, thermochemistry. Three hours of lecture, one conference per week, no laboratory section. S/NC.

CHEM 0120. Chemistry of the Environment. Focuses on understanding a number of environmental questions from the underlying laws and concepts of chemistry and physics. While some knowledge of math, physics and chemistry are useful, none is assumed. Concepts of chemistry and physics will be developed as needed.

CHEM 0190. Chemical Ecology: Pheromones, Poisons, and Chemical Messages. Plants and animals use chemicals to send and receive information about mating, identify potential hosts, defend themselves against enemies and pathogens and establish social networks. We will focus on the chemistry and biochemistry of these signals, with some examples of the behavioral and ecological consequences of chemical signaling.
CHEM 0330. Equilibrium, Rate, and Structure.
Explores the electronic structure of atoms and molecules, thermodynamics, solution equilibrium, electrolysis, chemical kinetics, and reaction mechanisms. Course includes lecture and laboratory sections. Laboratory cannot be taken without the lecture. Students who previously passed 0330 lab may be excused from repeating the lab portion of the course. Required background: CHEM 0100 or AP Chemistry 4 or CHEM Placement Test 8 or IBC Chemistry.

Fall CHEM0330 M01 16284 Arranged 'To Be Arranged'
Fall CHEM0330 S01 16292 MWF 10:00-10:50(18) 'To Be Arranged'
Fall CHEM0330 S02 16293 TTh 10:30-11:50(18) 'To Be Arranged'
Fall CHEM0330 C01 16295 M 12:00-12:50 (L Wang)
Fall CHEM0330 C02 16296 T 12:00-12:50 (L Wang)
Spr CHEM0330 M01 24772 Arranged 'To Be Arranged'
Spr CHEM0330 S01 24771 TTh 10:30-11:50(09) 'To Be Arranged'
Spr CHEM0330 C01 24773 M 12:00-12:50 'To Be Arranged'
Spr CHEM0330 C02 24774 T 12:00-12:50 'To Be Arranged'

CHEM 0330L. Equilibrium, Rate, and Structure Lab.
Please see course description for CHEM 0330.

Fall CHEM0330LL01 17022 M 1:00-4:50 (L Wang)
Fall CHEM0330LL02 17023 M 2:00-5:50 (L Wang)
Fall CHEM0330LL03 17024 T 1:00-4:50 (L Wang)
Fall CHEM0330LL04 17025 T 2:30-6:20 (L Wang)
Fall CHEM0330LL05 17026 W 1:00-4:50 (L Wang)
Fall CHEM0330LL06 17027 W 2:00-5:50 (L Wang)
Fall CHEM0330LL07 17028 Th 1:00-4:50 (L Wang)
Fall CHEM0330LL08 17029 Th 2:30-6:20 (L Wang)
Fall CHEM0330LL09 17030 F 1:00-4:50 (L Wang)
Fall CHEM0330LL10 17031 F 2:00-5:50 (L Wang)
Spr CHEM0330LL11 17032 Arranged (L Wang)
Spr CHEM0330LL01 25758 M 1:00-4:50 (L Wang)
Spr CHEM0330LL02 25759 M 2:00-5:50 (L Wang)
Spr CHEM0330LL03 25760 T 1:00-4:50 (L Wang)
Spr CHEM0330LL04 25761 Arranged (L Wang)
Spr CHEM0330LL05 25762 W 1:00-4:50 (L Wang)
Spr CHEM0330LL06 25764 W 2:00-5:50 (L Wang)
Spr CHEM0330LL07 25766 Th 1:00-4:50 (L Wang)
Spr CHEM0330LL08 25767 Th 2:30-6:20 (L Wang)
Spr CHEM0330LL09 25768 F 1:00-4:50 (L Wang)
Spr CHEM0330LL10 25769 F 2:00-5:50 (L Wang)
Spr CHEM0330LL11 25771 Arranged (L Wang)

CHEM 0332. Equilibrium, Rate and Structure - Tutorial.
The CHEM 0332 tutorial program offers students the opportunity to master the concepts taught in the fall semester CHEM 0330: Equilibrium, Rate and Structure course by focusing on active problem solving. Students who struggle in the fall CHEM 0330 course may be invited to join the tutorial program. Students accepted into the tutorial program begin by reviewing compound and reaction stoichiometry at the beginning of the spring semester. Tutorial students enroll in CHEM 0332 during the spring semester to complete their studies of equilibrium, acid-base equilibria, thermodynamics, atomic and molecular structure and kinetics. Students in the CHEM 0332 tutorial program complete weekly problem sets during the spring semester and participate in two mandatory, regularly scheduled problem sessions during each week of the spring semester. To qualify for consideration, the student must be struggling in the midterm exams and on track to pass the laboratory. Accepted students receive a grade of incomplete for the Fall CHEM 0330 course. Upon successful completion of the CHEM 0332 tutorial program in the spring semester, the incomplete in Fall CHEM 0330 is replaced by the student’s tutorial program grade.

An override by Ms Sheila Quigley is required.
Spr CHEM0332 S01 24775 Arranged 'To Be Arranged'
Spr CHEM0332 C01 24776 Arranged 'To Be Arranged'
Spr CHEM0332 C02 24777 Arranged 'To Be Arranged'
Spr CHEM0332 C03 24778 Arranged 'To Be Arranged'

CHEM 0350. Organic Chemistry.
Sequel to CHEM 0330. Investigates the constitution and properties of the different classes of organic compounds, with considerable attention to reaction mechanisms. The laboratory work involves an introduction to microscale preparative and analytical techniques of organic chemistry and the preparation of representative organic compounds. Three hours of lecture and five hours of prelaboratory and laboratory. Prerequisite: CHEM 0330.
Students MUST register for a common meeting, a lecture section, and a lab. If you previously completed CHEM 0350 laboratory but received a grade of no credit in the course, please register for lab section 11.

CHEM 0350L. Organic Chemistry Lab.
Please see course description for CHEM 0350.

CHEM 0360. Organic Chemistry.
Sequel to CHEM 0350. Investigates the constitution and properties of organic compounds at a fundamental level with an introduction to physical organic, bioorganic, and synthetic organic chemistry. Laboratory work is concerned with the identification and characterization of organic compounds, including modern instrumental methods. Three hours of lecture and five hours of prelaboratory and laboratory. Prerequisite: CHEM 0350.
Students MUST register for a lecture section, a lab and a conference. If you previously completed CHEM 0360 laboratory but received a grade of no credit in the course, please register for lab section 11.

CHEM 0360L. Organic Chemistry Lab.
Please see course description for CHEM 0360.

CHEM 0380. Physical and Bioinorganic Chemistry.
Examines aspects of physical and inorganic chemistry relevant to biochemistry: thermodynamics of hydrophobic and hydrophilic interactions, electrically charged membranes, coordination chemistry, active and passive transport, enzyme kinetics and mechanisms, metal-based drugs, and physical methods. Three hours of lecture and five hours of laboratory. Prerequisite: CHEM 0360 and MATH 0110 or 0170. Prerequisite or corequisite: PHYS 0440 or 0060. Students MUST register for a lecture section and a lab.
CHEM 0500. Inorganic Chemistry.
Examines the chemistry of main group and transition metal elements with treatment of covalent bonding and molecular structure along with the methods of studying inorganic compounds and reactions. Three hours of lecture and five hours of prelab and laboratory attendance. Prerequisite: CHEM 0360.

Students MUST register for a lecture section and a lab.

CHEM 0970. Undergraduate Research.
Prerequisite: permission of the staff. Permission should be requested before the end of the preceding semester. Section numbers vary by instructor. Please check Banner for the correct section number and CRN to use when registering for this course.

CHEM 0980. Undergraduate Research.
See Undergraduate Research (CHEM 0970) for course description. Section numbers vary by instructor. Please check Banner for the correct section number and CRN to use when registering for this course.

CHEM 0999. Chemistry and Art.
“Chemistry and Art” is an interdisciplinary course that explores different chemical concepts and techniques through the lenses of art and art history. The topics covered include paint and painting, stained glass; pottery and porcelains; gemstones and jewelry; color and art conservation. Drawing from early artistic texts, we will take a historically informed approach, connecting medieval stained-glass techniques, early pigmentation sourcing, and Qin dynasty pottery work to modern chemical conservation. Drawing from early artistic texts, we will take a historically informed approach, connecting medieval stained-glass techniques, early pigmentation sourcing, and Qin dynasty pottery work to modern chemical explanations. Throughout the course, lectures, discussions, hands-on activities, and writing are totally integrated and the chemistry principles and techniques behind art objects and art-making are introduced through a series of case studies. Students are asked to request overrides through Courses@Brown.Overrides will be granted after the first day of the class.

CHEM 1060. Advanced Inorganic Chemistry.
Covers the physical and chemical properties of transition metal compounds as well as current research topics in inorganic chemistry. Laboratory is designed for the practice of modern inorganic chemistry through the synthesis and spectroscopic characterization of air-sensitive transition metal compounds. Prerequisite: CHEM 0500.

CHEM 1140. Physical Chemistry: Quantum Chemistry.
An introduction to the quantum theory of chemical systems. Elements of quantum mechanics; electronic structure of atoms and molecules; study of molecular structure and behavior by spectroscopy; chemical bonding are all explored. Prerequisites: CHEM 0330, MATH 0180 or equivalent, PHYS 0030 and PHYS 0040 or PHYS 0050 and PHYS 0060 or PHYS 0070 and PHYS 0470 or ENGN 0030 and ENGN 0040.

Examines the question: Where does chemical equilibrium come from? Focuses on macroscopic perspectives on chemical systems and the molecular origins of macroscopic behavior along with elements of statistical mechanics, the laws of thermodynamics, and the relationships between the two. Prerequisite: CHEM 1140 or written permission of the instructor.

CHEM 1160. Physical Chemistry Laboratory.
An introduction to modern instrumentation and experimental techniques as applied to physical chemistry. Experiments will emphasize application of the ideas of spectroscopy, kinetics, statistical mechanics, and thermodynamics to systems of chemical and biochemical interest.

CHEM 1170. Environmental Chemistry.
A laboratory course using analytical methods to help in the study and description of several realistic environmental problems. Illustrates scientific methodology and measurement techniques as they apply to these important problems. A problem-solving course employing a kind of environmental chemical detective work. Two laboratory sessions per week. Prerequisites: MATH 0100 or the equivalent, or permission of the instructor. Enrollment limited to 8. Instructor permission required.

Introduction to computational tools used to analyze protein sequences and structures, DNA sequence analysis. RNA structure, biochemical pathways and the analysis of microarray data. Extensive use of programs such as AMBER, BLAST, PSIBLAST and a discussion of their limitations.

CHEM 1230. Chemical Biology.
This course covers topics at the interface of chemistry and biology and, specifically, the use of chemical tools to probe biological systems. Using examples from the recent literature, we will discuss using the central methods of chemistry, namely the ability to design and synthesize compounds with a particular set of properties, to analyze biological problems. Specific topics include molecular recognition of DNA, artificial enzymes, small molecule sensors, and in vivo imaging of proteins, nucleic acids, and cell-surface carbohydrates. Prerequisites: CHEM 0360 and BIOL 0280. If enrollment exceeds the limit, permission to enroll will be allotted in the order: 1) first year graduate students, 2) senior concentrators in Chemistry or Biochemistry 3) junior concentrators 4) other students. Students who have registered or have permission to enroll must attend the first three classes or risk losing their places to someone on the waiting list.

CHEM 1240. Biochemistry.
Examines the chemical, mechanistic, and structural basis for enzymatic catalysis. Uses examples from the recent literature to examine how the experimental and conceptual tools of chemical synthesis, isotopic labeling, stereochemistry, enzymology, kinetics, and protein structure can be brought to bear to unravel the chemical and physical principles underlying the enormous catalytic acceleration and exquisite structural specificity of enzyme-catalyzed reactions. Prerequisites: Strong background in organic chemistry (CHEM 0360, A or B performance preferable) plus at least one semester of Biochemistry (BIOL 0280). Enrollment limited to: 25 students, written permission required.

CHEM 1450. Advanced Organic Chemistry.
Lectures cover topics of current interest in organic reaction mechanisms, synthesis, and structure determination. Laboratory emphasizes spectroscopic and separation techniques and modern synthetic methods. Prerequisite: CHEM 0360. Students MUST register for a lecture section, conference and a lab.

CHEM 1560A. Molecular Modeling.
No description available.

CHEM 1560B. Techniques in Inorganic Chemistry.
No description available.

CHEM 1560C. Advanced Spectroscopy.
No description available.
CHEM 1560D. Chemistry and Biology of Naturally Occurring Antibiotics
Small molecules produced by organisms for chemical defense have long been exploited in medicine, biotechnology, and biological research. 1560D will examine the origins, uses, modes of action, and preparations of some of the most important and useful of these "antibiotic" molecules. Given the inter-disciplinary nature of this topic, this course is open to students with backgrounds in the biological and/or physical sciences. Familiarity with concepts of organic chemistry and biochemistry will be assumed.

CHEM 1560E. Biological Mass Spectrometry
This seminar course will survey the instrumentation, methods, and applications of modern biological mass spectrometry. Through lecture and interactive discussions, we will explore the fundamentals of mass spectrometry. We will then proceed to cover a series of topics relevant to protein and peptide analysis. The seminar will conclude with an exploration of recent developments in instrumentation or applications of particular interest to the participants. Recommended pre-requisites: CHEM 0360, BIOL 0280, PHYS 0040. Enrollment limited to 20.

CHEM 1560F. Organic Structure Analysis
CHEM 1560G. Nuclear Magnetic Resonance
These special topics courses cover the basics of modern NMR spectroscopy. Topics to be included are as follows: modern Fourier transform methodology, modern NMR instrumentation, and a comprehensive discussion of one and two dimensional experiments that are routinely performed. Topics such as coherence transfer and pulsed field gradients will also be included. Experimental methods covered in detail include COSY, TOCSY, HSQC, HMBC, NOSEY, ROSEY, EXSY and DOSY methodology. This course will not focus on structure determination or spectral interpretation but rather on experimental methodology.

CHEM 1560H. Chemical Glycobiology
This course examines the chemistry and biology of carbohydrates in living systems. Topics to be covered may include - principles of carbohydrate recognition, enzymes involved in synthesis and modification of carbohydrates, carbohydrates in bacterial/viral and other cellular interactions, glycomics, carbohydrate synthesis. Prerequisites: CHEM 0360 and BIOL 0280. Instructor permission required. Attendance at the first class meeting is required for enrollment.

CHEM 1560I. DNA Damage and Repair
This course analyzes the chemistry of DNA damage agents and the molecular mechanisms of DNA replication and DNA repair. We will also analyze the mutagenic and toxic consequences of modifications to DNA structure. Specific topics include the reactions of alkylating agents, ultraviolet radiation, and oxidizing radicals with DNA; additionally, chemotherapeutics that modify DNA will be discussed. Multiple cell repair pathways will be covered including base excision repair, nucleotide excision repair, mismatch repair, and direct reversal. Prerequisites: CHEM 0350, CHEM 0360, BIOL 0280, BIOL 1270, or by permission.

CHEM 1560J. Topics in Bioinorganic Chemistry
Covers current topics of bioinorganic chemistry with review of fundamental inorganic and biological chemistry. Topics include metal ion transport and storage, oxygen metabolism, electron transfer, respiration and photosynthesis, metal ion receptors and signaling, hydrolytic chemistry, metallo-neurochemistry, and medicinal bioinorganic chemistry. Students are strongly urged to complete both CHEM 0500 and CHEM 0360 prior to this special topics course.

CHEM 1560K. Computational Chemistry
Introduction to computational tools for studying the structure of molecules, chemical bonding and chemical reactions. A survey of computational approaches for calculating electron distribution such as molecular mechanics, semi-empirical and ab initio methods (Hartree-Fock, configuration interaction, perturbation theory and density functional theory) will be given. Methods for calculating dynamics of atoms in molecular vibration and chemical reactions will be covered. The course is intended for seniors and graduate students in all subdivisions of chemistry. The goal is to make students capable of using research level tools and carry out simple calculations related to their research interests.

CHEM 1560L. Modern Natural Product Biosynthesis
This course will cover the biosynthesis of the major classes of natural products - polyketides, non-ribosomal peptides, including beta-lactam antibiotics, terpenes, alkaloids and vitamins. The readings from original literature will cover the chemical logic and mechanisms of biosynthetic pathways and individual reactions, including isotopic labeling for whole-cell feeding experiments, stable isotopic NMR analysis, and mass spectrometry. Modern topics include genomics of natural product biosynthesis, genome mining, and pathway engineering. Prerequisites: CHEM 0350 and 0360. Recommended: CHEM 1230, 1240, or 1450. Enrollment limited to 25 juniors and seniors.

CHEM 1560M. Applied Materials Chemistry
Materials chemistry is the study of the synthesis, structure, properties, and application of solid materials. Our technology-driven world is fueled by advances in materials chemistry with examples of application in areas such as microelectronics, polymers, and energy technology. This course will explain the application of materials chemistry through the materials properties and characterization, detailing how the crystalline and molecular structure of materials can be related to electronic, optical, thermal, and mechanical properties.

CHEM 1560N. Organometallic Chemistry
Modern organometallic chemistry continues to find unique applications including next generation lighting displays, therapeutics and imaging, energy science, and green chemical synthesis. In this course we will briefly review fundamentals of inorganic chemistry (MO theory, ligand field theory, Pearson’s HSAB theory), and then delve into the structure, bonding, synthesis, reactivity, and mechanisms associated with organometallic complexes and their associated applications. Significant emphasis will be placed on effective oral and written communication skills, with frequent peer and instructor feedback provided. Prerequisites: CHEM 0360, CHEM 0500. PLEASE NOTE: This class is WRIT designated for Undergraduates Only. Graduate Students register for CHEM 2310.

CHEM 1560P. Applications of Modern Physical Methods in Synthesis
The modern synthetic chemist leverages a wide range of physical methods to answer research questions in diverse application areas ranging from renewable energy, medicine, materials, complex molecule synthesis, and others. Students will develop a working knowledge of modern techniques applied to synthesis, learning fundamental principles, experimental limitations, and interpretation of experimental results. Selected techniques may include: Nuclear Magnetic Resonance (NMR), Electron Paramagnetic Resonance (EPR), Fluorimetry, Absorption Spectroscopy (UV-Vis, IR, X-ray), Diffraction (X-ray), Magnetometry, Electrochemistry, and Mass-Spectrometry. Emphasis will be placed on how techniques are relevant in current research areas, and the instrumental capabilities available at Brown University.

CHEM 1620A. Photoacoustics
Prerequisite: CHEM 1140 or equivalent.

CHEM 1620B. Spectroscopy
Prerequisite: CHEM 1140 or equivalent.

CHEM 1620C. Topics in Modern Physical Chemistry
No description available.

CHEM 1660. Instrumental Analysis with Environmental Applications
This course covers the principles and practical applications of important analytical chemistry tools used to study environmental problems, including discussions of method selection and statistical treatment of data. Students will strategize and implement a study of a field site. Includes lab sessions with hands-on experience of instrumental analysis using atomic and molecular spectroscopic techniques, separations by gas and liquid chromatography, and electrochemical methods. Prerequisite: CHEM 0330 or GEOL 1370. Enrollment limited to 20. Instructor permission required.
Focuses on synthesis, properties, and applications of nanoscale materials. It begins with the introduction to size-dependent properties and to general characterization methods of nanomaterials. It then outlines the synthesis, surface chemistry and self-assembly of nanomaterials. It further reviews catalytic, optical and magnetic properties of nanomaterials. Finally, the course highlights the applications of nanomaterials in information storage, energy conversion, and biomedicine. Prerequisites: CHEM0350, PHYS 0030 or 0050, BIOLOGY recommended. Fall CHEM1700 S01 16340 MW 11:00-11:50(16) 'To Be Arranged'

CHEM 2010. Advanced Thermodynamics.
Fundamental principles of macroscopic equilibrium thermodynamics. The three laws of thermodynamics, the thermodynamic potentials, temperature scales, heat engines and refrigerators, entropy, kinetic theory, and transport phenomena. Applications to solids, fluids, and magnetic systems; Gibbs relations, first and second order phase transitions, thermal radiation, gas expansions. Fall CHEM2010 S01 16341 TTh 9:00-10:20(02) 'To Be Arranged'

Introduction to modern equilibrium statistical mechanics, including the classical and quantum descriptions of ideal gases, the molecular basis of thermodynamics, the concepts of ensembles and fluctuations, and the implications of quantum mechanical indistinguishability. Applications include chemical and phase equilibria, the transition-state theory of chemical reaction rates, and the theory of liquids. Spr CHEM2020 S01 24789 MW 9:00-9:50(02) 'To Be Arranged'

CHEM 2210. Chemical Crystallography.
Introduces the principles of crystallography (plane groups, point groups, space groups, Bravais lattice, crystal classes), crystallographic methods (single-crystal, powder XRD, macromolecular), strategies for data collection, methods for data reduction, and structure interpretation; reviews modern crystal structure databases (CSD, ICSD) and search engines; reviews the historical development of crystallography and the scope, potential and application of X-ray analysis. Fall CHEM2210 S01 16342 TTh 10:30-11:50(13) (J. Robinson)

CHEM 2310. Organometallic Chemistry.
Modern organometallic chemistry continues to find unique applications including next generation lighting displays, therapeutics and imaging, energy science, and green chemical synthesis. In this course we will briefly review fundamentals of inorganic chemistry (MO theory, ligand field theory, Pearson’s HSAB theory), and then delve into the structure, bonding, synthesis, reactivity, and mechanisms associated with organometallic complexes and their associated applications. Significant emphasis will be placed on effective oral and written communication skills, with frequent peer and instructor feedback provided. Prerequisites: CHEM 0360, CHEM 0500. PLEASE NOTE: This class is WRIT designated for Undergraduates Only. Graduate Students register for CHEM 2310. Fall CHEM2310 S01 16342 TTh 10:30-11:50(13) (J. Robinson)

CHEM 2320. Solid State Chemistry.
This course focuses on descriptive understanding of structures and properties of inorganic materials. It covers symmetry operations in crystals, crystal structure, physical properties of inorganic materials, materials phase diagram and preparation, and solid state electrochemistry for battery, fuel cell and supercapacitor applications. Prerequisites: CHEM 0500 and 1060 or equivalents or written permission. Recommended for seniors and first-year graduate students. Spr CHEM2320 S01 24790 TTh 10:30-11:50(09) 'To Be Arranged'

Detailed examination of organic reaction mechanisms, reactive intermediates, and the methods employed for their characterization (e.g., kinetics, free energy relationships, isotope effects, molecular orbital theory, spectroscopy, and product distributions). Topics may include concerted, free radical, elimination, and photochemical reactions, and the chemistry of radicals, carbocations, carbanions, and carbenes. Fall CHEM2410 S01 16343 MW 10:00-10:50(14) 'To Be Arranged'

CHEM 2420. Organic Reactions.
Study of organic reactions and reaction mechanisms. Discussion and analysis of organic transformations. Topics can include arrow pushing strategies and synthetic methods. Fall CHEM2420 S01 16346 TTh 9:00-10:20(02) 'To Be Arranged'

CHEM 2430. Synthetic Organic Chemistry.
Methods, strategies, and mechanisms. Topics may include the chemistry of anions, cations, and radicals, concerted reactions, conformational analysis, and stereochemistry. Spr CHEM2430 S01 24791 MWF 11:00-11:50(04) 'To Be Arranged'

CHEM 2770. Quantum Mechanics.
Semester I: Time independent quantum mechanics and its application to atomic and molecular problems. Discussions of modern theories of electronic structure, chemical bonding, and molecular spectroscopy. Prerequisite: CHEM 1140 or equivalent. Fall CHEM2770 S01 16347 TTh 10:30-11:50(13) 'To Be Arranged'

CHEM 2780. Quantum Mechanics.
Semester II: Lectures focus on the theory and application of electronic structure methods to describe both time-independent and time-dependent phenomena in chemical physics. Modern methods including Hartree-Fock Theory, Moller Plesset Perturbation Theory, Configuration Interaction, Coupled Cluster Theory, and Density Functional Theory will be described. Numerical techniques for implementing these methods will also be introduced and applications based upon problems in molecular spectroscopy will be outlined. Prerequisite: CHEM 2770. Spr CHEM2780 S01 24794 TTh 10:30-11:50(09) 'To Be Arranged'

CHEM 2810. Departmental Seminars.
No description available.

CHEM 2820. Departmental Seminars.
No description available.

CHEM 2870. Departmental Colloquia.
Open to first year chemistry graduate students only. Fall CHEM2870 S01 16348 F 4:00-5:20 'To Be Arranged'

CHEM 2880. Departmental Colloquia.
No description available. Open to graduate students only.

CHEM 2920A. Chemistry and Physics of Amorphous Materials.
No description available.

CHEM 2920B. Organic Spectroscopic Methods.
No description available.

CHEM 2920C. Topics in Modern Spectroscopy.
No description available.

CHEM 2970. Preliminary Examination Preparation.
For graduate students who have met the tuition requirement and are paying the registration fee to continue active enrollment while preparing for a preliminary examination. Fall CHEM2970 S01 15261 Arranged 'To Be Arranged'

CHEM 2980. Research.
Section numbers vary by instructor. Please check Banner for the correct section number and CRN to use when registering for this course.

CHEM 2990. Thesis Preparation.
For graduate students who have met the residency requirement and are continuing research on a full time basis. Fall CHEM2990 S01 15262 Arranged 'To Be Arranged'

CHEM XLIST. Courses of Interest to Students wishing to Study Chemistry.
Font Notice

This document should contain certain fonts with restrictive licenses. For this draft, substitutions were made using less legally restrictive fonts. Specifically:

Helvetica was used instead of Arial.
The editor may contact Leepfrog for a draft with the correct fonts in place.