Chemical Physics

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http://www.columbia.edu/cu/chemistry/

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Program Manager for Undergraduate Studies: Dr. Vesna Gasperov, 211A Havemeyer; 212-854-2017; vg2231@columbia.edu

Biochemistry Advisers:

Biology: Prof. Brent Stockwell, 1208 Northwest Corner Building; 212-854-2919; stockwell@biology.columbia.edu

Chemistry, the study of molecules, is a central science interesting for its own sake but also necessary as an intellectual link to the other sciences of biology, physics, and environmental science. Faculty find the various disciplines of chemistry fascinating because they establish intellectual bridges between the macroscopic or human-scale world that we see, smell, and touch, and the microscopic world that affects every aspect of our lives. The study of chemistry begins on the microscopic scale and extends to engage a variety of different macroscopic contexts.

Chemistry is currently making its largest impact on society at the nexus between chemistry and biology and the nexus between chemistry and engineering, particularly where new materials are being developed. A typical chemistry laboratory now has more computers than test tubes and no longer smells of rotten eggs.

The chemistry department majors are designed to help students focus on these new developments and to understand the factors influencing the nature of the discipline. Because the science is constantly changing, courses change as well, and while organic and physical chemistry remain the bedrock courses, they too differ greatly from the same courses 40 years ago. Many consider biochemistry to be a foundation course as well. Although different paths within the chemistry major take different trajectories, there is a core that provides the essential foundation students need regardless of the path they choose. Students should consider majoring in chemistry if they share or can develop a fascination with the explanatory power that comes with an advanced understanding of the nature and influence of the microscopic world of molecules.

Students who choose to major in chemistry may elect to continue graduate study in this field and obtain a Ph.D. which is a solid basis for a career in research, either in the industry or in a university. A major in chemistry also provides students with an astonishing range of career choices such as working in the chemical or pharmaceutical industries or in many other businesses where a technical background is highly desirable. Other options include becoming a financial analyst for a technical company, a science writer, a high school chemistry teacher, a patent attorney, an environmental consultant, or a hospital laboratory manager, among others. The choices are both numerous and various as well as intellectually exciting and personally fulfilling.

Advanced Placement

The department grants advanced placement (AP) credit for a score of 4 or 5 or the equivalent. The amount of credit granted is based on the results of the department placement exam and completion of the requisite course. Students who are placed into CHEM UN1604 Intensive General Chemistry (Lecture) are granted 3 points of credit; students who are placed into CHEM UN2045 Intensive Organic Chemistry I (Lecture)-CHEM UN2046 Intensive Organic Chemistry II (Lecture) are granted 6 points of credit. In either case, credit is granted only upon completion of the course with a grade of C or better. Students must complete a department placement exam prior to registering for either of these courses.

Programs of Study

The Department of Chemistry offers four distinct academic major programs for undergraduates interested in professional-level training and education in the chemical sciences: chemistry, chemical physics, biochemistry and environmental chemistry. For students interested in a program of less extensive study and coursework, the department offers a concentration in chemistry.

Course Information

The results of the placement exam are used to advise students which track to pursue. The Department of Chemistry offers three different tracks. Students who wish to take Track 2 or 3 classes must take the placement exam. Students who wish to pursue Track 1 classes do not need to take the placement exam.

Track Information

In the first year, Track 1 students with one year of high school chemistry take a one-year course in general chemistry, and the one-term laboratory course that accompanies it. In the second year, students study organic chemistry, and take organic chemistry laboratory.

Students who qualify by prior examination during orientation week can place into the advanced tracks. There are two options. Track 2 students take, in the fall term, a special one-term intensive course in general chemistry in place of the one-year course. In the second year, students study organic chemistry and take organic chemistry laboratory. Track 3 students take a one-year course in organic chemistry for first-year students and the one-term intensive general chemistry laboratory course. In the second year, students enroll in physical chemistry and the organic chemistry laboratory course.

Additional information on the tracks can be found in the Requirements section.

Additional Courses

First-year students may also elect to take CHEM UN2408. This seminar focuses on topics in modern chemistry, and is offered to all students who have taken at least one semester of college chemistry and have an interest in chemical research.

Biochemistry (BIOC UN3501, BIOC UN3512) is recommended for students interested in the biomedical sciences.

Physical chemistry (CHEM UN3079-CHEM UN3080), a one-year program, requires prior preparation in mathematics and physics. The accompanying laboratory is CHEM UN3085-CHEM UN3086.

Also offered are a senior seminar (CHEM UN3920); advanced courses in biochemistry, inorganic, organic, and physical chemistry; and an introduction to research (CHEM UN3098).
Sample Programs

Some typical programs are shown below. Programs are crafted by the student and the director of undergraduate studies to meet individual needs and interests.

### Track 1

**First Year**
- CHEM UN1403 General Chemistry I (Lecture)
- CHEM UN1404 General Chemistry II (Lecture)
- CHEM UN1500 General Chemistry Laboratory
- CHEM UN2408 First-Year Seminar in Chemical Research

Calculus and physics as required.

**Second Year**
- CHEM UN2443 Organic Chemistry I (Lecture)
- CHEM UN2444 Organic Chemistry II (Lecture)
- CHEM UN2493 Organic Chemistry Laboratory I (Techniques)
- CHEM UN2494 Organic Chemistry Laboratory II (Synthesis)

Calculus and physics as required.

**Third Year**
- CHEM UN3079 Physical Chemistry I
- CHEM UN3080 Physical Chemistry II
- BIOC UN3501 Biochemistry: Structure and Metabolism
- CHEM UN3546 Advanced Organic Chemistry Laboratory
- CHEM UN3098 Supervised Independent Research

**Fourth Year**
- CHEM UN3085 Physical and Analytical Chemistry Laboratory I
- CHEM UN3086 Physical and Analytical Chemistry Laboratory II
- CHEM UN3920 Senior Seminar in Chemical Research
- CHEM GU4071 Inorganic Chemistry

Advanced courses (4000-level or higher)

### Track 2

**First Year**
- CHEM UN1507 Intensive General Chemistry Laboratory
- CHEM UN1604 Intensive General Chemistry (Lecture)
- CHEM UN2408 First-Year Seminar in Chemical Research

Calculus and physics as required.

**Second Year**
- CHEM UN2443 Organic Chemistry I (Lecture)
- CHEM UN2444 Organic Chemistry II (Lecture)
- CHEM UN2493 Organic Chemistry Laboratory I (Techniques)
- CHEM UN2494 Organic Chemistry Laboratory II (Synthesis)

Calculus and physics as required.

**Third Year**
- CHEM UN3079 Physical Chemistry I
- CHEM UN3080 Physical Chemistry II
- CHEM UN3545 Intensive Organic Chemistry Laboratory
- CHEM UN3546 Advanced Organic Chemistry Laboratory

Calculus and physics as required.

**Fourth Year**
- CHEM UN3085 Physical and Analytical Chemistry Laboratory I
- CHEM UN3086 Physical and Analytical Chemistry Laboratory II
- CHEM UN3920 Senior Seminar in Chemical Research

Advanced courses (4000-level or higher)

### Track 3

**First Year**
- CHEM UN1507 Intensive General Chemistry Laboratory
- CHEM UN2045 Intensive Organic Chemistry I (Lecture)
- CHEM UN2046 Intensive Organic Chemistry II (Lecture)
- CHEM UN2408 First-Year Seminar in Chemical Research

Calculus and Physics as required.

**Second Year**
- CHEM UN3079 Physical Chemistry I
- CHEM UN3080 Physical Chemistry II
- CHEM UN2545 Intensive Organic Chemistry Laboratory
- CHEM UN3546 Advanced Organic Chemistry Laboratory

Calculus and physics as required.

**Third Year**
- BIOC UN3501 Biochemistry: Structure and Metabolism
- CHEM UN3085 Physical and Analytical Chemistry Laboratory I
- CHEM UN3086 Physical and Analytical Chemistry Laboratory II
- CHEM UN3098 Supervised Independent Research
- CHEM GU4071 Inorganic Chemistry

**Fourth Year**
- CHEM UN3920 Senior Seminar in Chemical Research

Advanced courses (4000-level or higher)

### Professors

Bruce J. Berne
Louis Brus
Virginia W. Cornish
Kenneth B. Eisenhal
Richard A. Friesner
Ruben Gonzalez
Laura Kaufman
James L. Leighton
Ann E. McDermott
Wei Min
Jack R. Norton
Colin Nuckolls
Gerard Parkin
David R. Reichman
Tomislav Rovis
Dalibor Sames
Brent Stockwell
James J. Valentini
Latha Venkataraman
Xiaoyang Zhu

### Associate Professors

Angelo Cacciuto
Luis Campos
Jonathan Owen
Assistant Professors
Timothy Berkelbach
Xavier Roy
Neel Shah

Senior Lecturer
Luis Avila
Fay Ng
Karen Phillips

Lecturers
Robert Beer
John Decatur
Charles E. Doubleday
Sarah Hansen
Ruben Savizky
Talha Siddiqui

Guidelines for all Chemistry Majors, Concentrators, and Interdepartmental Majors

Students majoring in chemistry or in one of the interdepartmental majors in chemistry should go to the director of undergraduate studies or the undergraduate program manager in the Department of Chemistry to discuss their program of study. Chemistry majors and interdepartmental majors usually postpone part of the Core Curriculum beyond the sophomore year.

Chemistry Tracks

All students who wish to start with Track 2 or 3 courses must take a placement exam. The results of the placement exam are used to advise students which track to pursue. Unless otherwise specified below, all students must complete one of the following tracks:

Track 1

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM UN1403</td>
<td>General Chemistry I (Lecture)</td>
</tr>
<tr>
<td>CHEM UN1404</td>
<td>General Chemistry II (Lecture)</td>
</tr>
<tr>
<td>CHEM UN1500</td>
<td>General Chemistry Laboratory</td>
</tr>
<tr>
<td>CHEM UN2443</td>
<td>Organic Chemistry I (Lecture)</td>
</tr>
<tr>
<td>CHEM UN2444</td>
<td>Organic Chemistry II (Lecture)</td>
</tr>
<tr>
<td>CHEM UN2493</td>
<td>Organic Chemistry Laboratory I (Techniques)</td>
</tr>
<tr>
<td>CHEM UN2494</td>
<td>Organic Chemistry Laboratory II (Synthesis)</td>
</tr>
</tbody>
</table>

Track 2

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM UN1500</td>
<td>General Chemistry Laboratory</td>
</tr>
<tr>
<td>CHEM UN1507</td>
<td>Intensive General Chemistry Laboratory</td>
</tr>
<tr>
<td>CHEM UN1604</td>
<td>Intensive General Chemistry (Lecture)</td>
</tr>
<tr>
<td>CHEM UN2443</td>
<td>Organic Chemistry I (Lecture)</td>
</tr>
<tr>
<td>CHEM UN2444</td>
<td>Organic Chemistry II (Lecture)</td>
</tr>
</tbody>
</table>

Track 3

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM UN1507</td>
<td>Intensive General Chemistry Laboratory</td>
</tr>
<tr>
<td>CHEM UN2045</td>
<td>Intensive Organic Chemistry I (Lecture)</td>
</tr>
<tr>
<td>CHEM UN2046</td>
<td>Intensive Organic Chemistry II (Lecture)</td>
</tr>
<tr>
<td>CHEM UN2545</td>
<td>Intensive Organic Chemistry Laboratory</td>
</tr>
</tbody>
</table>

Physics Sequences

Unless otherwise specified below, all students must complete one of the following sequences:

Sequence A

For students with limited background in high school physics:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS UN1401</td>
<td>Introduction To Mechanics and Thermodynamics</td>
</tr>
<tr>
<td>PHYS UN1402</td>
<td>Introduction To Electricity, Magnetism, and Optics</td>
</tr>
<tr>
<td>PHYS UN1403</td>
<td>Introduction to Classical and Quantum Waves</td>
</tr>
</tbody>
</table>

For chemistry majors, the following laboratory courses are recommended, NOT required. For chemical physics majors, the following laboratory courses are required:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS UN1494</td>
<td>Introduction to Experimental Physics</td>
</tr>
<tr>
<td>PHYS UN2699</td>
<td>Experiments in Classical and Modern Physics</td>
</tr>
<tr>
<td>PHYS UN3081</td>
<td>Intermediate Laboratory Work</td>
</tr>
</tbody>
</table>

Sequence B

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS UN1601</td>
<td>Physics, I: Mechanics and Relativity</td>
</tr>
<tr>
<td>PHYS UN1602</td>
<td>Physics, II: Thermodynamics, Electricity, and Magnetism</td>
</tr>
<tr>
<td>PHYS UN2601</td>
<td>Physics, III: Classical and Quantum Waves</td>
</tr>
<tr>
<td>PHYS UN3081</td>
<td>Intermediate Laboratory Work</td>
</tr>
</tbody>
</table>

For chemistry majors, the following laboratory courses are recommended NOT required. For chemical physics majors, the following laboratory courses are required:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS UN2699</td>
<td>Experiments in Classical and Modern Physics</td>
</tr>
</tbody>
</table>

Sequence C

For students with advanced preparation in physics and mathematics:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
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</thead>
<tbody>
<tr>
<td>PHYS UN2801</td>
<td>Accelerated Physics I</td>
</tr>
<tr>
<td>PHYS UN2802</td>
<td>and Accelerated Physics II</td>
</tr>
</tbody>
</table>

For chemistry majors, the following laboratory courses are recommended NOT required. For chemical physics majors, the following laboratory courses are required:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS UN2699</td>
<td>Experiments in Classical and Modern Physics</td>
</tr>
<tr>
<td>PHYS UN3081</td>
<td>Intermediate Laboratory Work</td>
</tr>
</tbody>
</table>
### Major in Chemistry

Select one of the tracks outlined above in *Guidelines for all Chemistry Majors, Concentrators, and Interdepartmental Majors* and complete the following lectures and labs.

**Chemistry**

Select one of the chemistry tracks outlined above.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM UN2408</td>
<td>First-Year Seminar in Chemical Research</td>
</tr>
<tr>
<td></td>
<td>(Recommended NOT required)</td>
</tr>
<tr>
<td>CHEM UN3079</td>
<td>Physical Chemistry I</td>
</tr>
<tr>
<td>CHEM UN3080</td>
<td>Physical Chemistry II</td>
</tr>
<tr>
<td>CHEM UN3085</td>
<td>Physical and Analytical Chemistry Laboratory I</td>
</tr>
<tr>
<td>CHEM UN3086</td>
<td>Physical and Analytical Chemistry Laboratory II</td>
</tr>
<tr>
<td>CHEM UN3546</td>
<td>Advanced Organic Chemistry Laboratory</td>
</tr>
<tr>
<td>CHEM GU4071</td>
<td>Inorganic Chemistry</td>
</tr>
</tbody>
</table>

Select one course from the following:

- CHEM UN3098 Supervised Independent Research
- OR Chemistry courses numbered CHEM GU4000 or above

**Physics**

Select one of the physics sequences outlined above in the Guidelines section.

**Mathematics**

Select one of the following sequences:

- Four semesters of calculus:
  - MATH UN1101  Calculus I
  - MATH UN1102  and Calculus II
  - MATH UN1201  and Calculus III
  - MATH UN1202  and Calculus IV
- Two semesters of honors mathematics:
  - MATH UN1207  Honors Mathematics A
  - MATH UN1208  and Honors Mathematics B

### Major in Biochemistry

Select one of the tracks outlined above in *Guidelines for all Chemistry Majors, Concentrators, and Interdepartmental Majors* and complete the following lectures and labs.

**Chemistry**

Select one of the chemistry tracks outlined above.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM UN2408</td>
<td>First-Year Seminar in Chemical Research</td>
</tr>
<tr>
<td></td>
<td>(Recommended NOT required)</td>
</tr>
<tr>
<td>CHEM UN3079</td>
<td>Physical Chemistry I</td>
</tr>
<tr>
<td>CHEM UN3080</td>
<td>Physical Chemistry II</td>
</tr>
</tbody>
</table>

**Biology**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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</thead>
<tbody>
<tr>
<td>BIOL UN1908</td>
<td>First-Year Seminar in Modern Biology</td>
</tr>
<tr>
<td></td>
<td>(Recommended NOT required)</td>
</tr>
<tr>
<td>BIOL UN2005</td>
<td>Introductory Biology I: Biochemistry, Genetics &amp; Molecular Biology</td>
</tr>
<tr>
<td>BIOL UN2006</td>
<td>Introductory Biology II: Cell Biology, Development &amp; Physiology</td>
</tr>
<tr>
<td>BIOC UN3501</td>
<td>Biochemistry: Structure and Metabolism</td>
</tr>
<tr>
<td>BIOC UN3512</td>
<td>Molecular Biology</td>
</tr>
</tbody>
</table>

**Physics**

Select one of the following physics sequences:

- Sequence A:
  - PHYS UN1201 General Physics I
  - PHYS UN1202 and General Physics II
  - PHYS UN1401 Introduction To Mechanics and Thermodynamics
  - PHYS UN1402 and Introduction To Electricity, Magnetism, and Optics
  - PHYS UN1403 and Introduction to Classical and Quantum Waves (PHYS UN1403 is recommended NOT required)

- Sequence B:
  - PHYS UN1601 Physics, I: Mechanics and Relativity
  - PHYS UN1602 and Physics, II: Thermodynamics, Electricity, and Magnetism
  - PHYS UN2601 and Physics, III: Classical and Quantum Waves (PHYS UN2601 is recommended but not required)

- Sequence C:
  - PHYS UN2801 Accelerated Physics I
  - PHYS UN2802 and Accelerated Physics II

- Sequence D:
  - MATH UN1101 Calculus I
  - MATH UN1102 and Calculus II
  - MATH UN1201 and Calculus III
  - MATH UN1202 and Calculus IV

**Mathematics**

Select one of the following sequences:

- Two semesters of calculus:
  - MATH UN1101 Calculus I
  - MATH UN1102 and Calculus II
  - MATH UN1201 and Calculus III
  - MATH UN1202 and Calculus IV

- Two semesters of honors mathematics:
  - MATH UN1207 Honors Mathematics A
  - MATH UN1208 and Honors Mathematics B
  - AP credit and one term of calculus (Calculus II or higher)

**Additional Courses**

Select two of the following upper level laboratory courses (one should be a Biology lab):

- BIOL UN3040 Lab in Molecular Biology
  - BIOL UN2501 and Contemporary Biology Laboratory
- BIOL UN3050 Project Laboratory In Protein Biochemistry
- BIOL UN3052 Project Laboratory in Molecular Genetics
- BIOL UN3500 Independent Biological Research
- CHEM UN3085 Physical and Analytical Chemistry Laboratory I
- CHEM UN3086 Physical and Analytical Chemistry Laboratory II
- CHEM UN3098 Supervised Independent Research
- CHEM UN3546 Advanced Organic Chemistry Laboratory

Select any three courses from the following:

- CHEM GU4071 Inorganic Chemistry
- CHEM GU4102 Chemistry for the Brain
- CHEM GU4147 Advanced Organic Chemistry
- BIOC GU4323 Biophysical Chemistry I
- BIOC GU4324 Biophysical Chemistry II
- MATH UN3027 Ordinary Differential Equations
  - or MATH UN2030 Ordinary Differential Equations

One additional semester of calculus

One additional semester of honors math:

- MATH UN1207 Honors Mathematics A
- MATH UN1208 and Honors Mathematics B

Any biology course at the 3000/4000 level for 3 or more points. The following are recommended:
Major in Chemical Physics

Select one of the tracks outlined above in Guidelines for all Chemistry Majors, Concentrators, and Interdepartmental Majors and complete the following lectures and labs.

Chemistry

Select one of the chemistry tracks outlined above.

CHEM UN3079  Physical Chemistry I
CHEM UN3080  Physical Chemistry II
CHEM UN3085  Physical and Analytical Chemistry Laboratory I
CHEM UN3086  Physical and Analytical Chemistry Laboratory II
CHEM UN3098  Supervised Independent Research
CHEM UN3920  Senior Seminar in Chemical Research

Earth and Environmental Science

Select two of the following three courses:

EESC UN2100  Earth's Environmental Systems: The Climate System
EESC UN2200  Earth's Environmental Systems: The Solid Earth System
EESC UN2300  Earth's Environmental Systems: The Life System

Additional course required:

EESC UN3101  Geochemistry for a Habitable Planet

Select one of the following labs:

EESC BC3016  Environmental Measurements
CHEM UN3085  Physical and Analytical Chemistry Laboratory I

Physics

Select one of the following physics sequences:

Sequence A:
PHYS UN1201  General Physics I
PHYS UN1202  General Physics II

Sequence B:
PHYS UN1401  Introduction To Mechanics and Thermodynamics
PHYS UN1402  Introduction To Electricity, Magnetism, and Optics
PHYS UN1403  Introduction to Classical and Quantum Waves (Recommended NOT required)

Sequence C:
PHYS UN1601  Physics, I: Mechanics and Relativity
PHYS UN1602  Physics, II: Thermodynamics, Electricity, and Magnetism
PHYS UN2501  Physics, III: Classical and Quantum Waves (Recommended, not required)

Sequence D:
PHYS UN2801  Accelerated Physics I
PHYS UN2802  Accelerated Physics II

Mathematics

Select one of the following sequences:

Four semesters of calculus:
MATH UN1101  Calculus I
- MATH UN1102  and Calculus II
- MATH UN1201  and Calculus III
- MATH UN1202  and Calculus IV

Two semesters of honors mathematics:
MATH UN1207  Honors Mathematics A
- MATH UN1208  and Honors Mathematics B
- MATH UN3027  and Ordinary Differential Equations

Two semesters of advanced calculus:
MATH UN1202  Calculus IV
- MATH UN3027  and Ordinary Differential Equations

Major in Environmental Chemistry

The requirements for this program were modified on February 1, 2016. Students who declared this program before this date should contact the director of undergraduate studies for the department in order to confirm their correct course of study.

Select one of the tracks outlined above in Guidelines for all Chemistry Majors, Concentrators, and Interdepartmental Majors and complete the following lectures and labs.

Chemistry

Select one of the chemistry tracks outlined above. A second semester of Organic Chemistry lecture is recommended NOT required.

CHEM UN3079  Physical Chemistry I
CHEM GU4071  Inorganic Chemistry

The following courses are recommended NOT required:

CHEM UN2408  First-Year Seminar in Chemical Research
CHEM UN3920  Senior Seminar in Chemical Research

Earth and Environmental Science

Select two of the following three courses:

EESC UN2100  Earth's Environmental Systems: The Climate System
EESC UN2200  Earth's Environmental Systems: The Solid Earth System
EESC UN2300  Earth's Environmental Systems: The Life System

Additional course required:

EESC UN3101  Geochemistry for a Habitable Planet

Select one of the following labs:

EESC BC3016  Environmental Measurements
CHEM UN3085  Physical and Analytical Chemistry Laboratory I

Select one option for Independent Research in Environmental Chemistry:

EESC BC3800  Senior Research Seminar
- EESC BC3801  Senior Research Seminar
CHEM UN3098  Supervised Independent Research (It is strongly recommended to take CHEM UN3920 if taking CHEM UN3098)

Physics

Select one of the following physics sequences:

Sequence A:
PHYS UN1201  General Physics I
PHYS UN1202  General Physics II

Sequence B:
PHYS UN1401  Introduction To Mechanics and Thermodynamics
PHYS UN1402  Introduction To Electricity, Magnetism, and Optics
PHYS UN1403  Introduction to Classical and Quantum Waves (Recommended NOT required)

Sequence C:
PHYS UN1601  Physics, I: Mechanics and Relativity
PHYS UN1602  Physics, II: Thermodynamics, Electricity, and Magnetism
PHYS UN2501  Physics, III: Classical and Quantum Waves (Recommended, not required)

Sequence D:
PHYS UN2801  Accelerated Physics I
PHYS UN2802  Accelerated Physics II

Mathematics

Two semesters of calculus:
MATH UN1101  Calculus I
MATH UN1102  Calculus II
Additional Courses
Select any two of the following:

Chemistry:
CHEM UN3080 Physical Chemistry II
CHEM GU4103 Organometallic Chemistry
CHEM GU4147 Advanced Organic Chemistry

Earth and Environmental Science:
EESC BC3017 Environmental Data Analysis
EESC BC3025 Hydrology
EESC GU4008 Introduction to Atmospheric Science
EESC GU4009 Chemical Geology
EESC GU4040 Climate Thermodynamics and Energy Transfer
EESC GU4050 Global Assessment and Monitoring Using Remote Sensing
EESC GU4600 Earth Resources and Sustainable Development
EESC GU4835 Wetlands and Climate Change
EESC GU4885 The Chemistry of Continental Waters
EESC GU4888 Stable Isotope Geochemistry
EESC GU4924 Introduction to Atmospheric Chemistry
EESC GU4925 Principles of Physical Oceanography
EESC GU4926 Principles of Chemical Oceanography

Earth and Environmental Engineering:
EAEE E4001 Industrial ecology of earth resources
EAEE E4003 Aquatic chemistry

Mathematics:
One additional semester of calculus

Concentration in Chemistry

No more than four points of CHEM UN3098 Supervised Independent Research may be counted toward the concentration.

Select one of the three chemistry tracks listed below.

PHYS UN1201 - PHYS UN1202 General Physics I and General Physics II

Two semesters of calculus

Chemistry Tracks

Track 1
CHEM UN1403 General Chemistry I (Lecture)
CHEM UN1404 General Chemistry II (Lecture)
CHEM UN1500 General Chemistry Laboratory

Select 22 points of chemistry at the 2000-level or higher (excluding CHEM UN2408).

Track 2
CHEM UN1500 General Chemistry Laboratory
CHEM UN1507 Intensive General Chemistry Laboratory
CHEM UN1604 Intensive General Chemistry (Lecture)

Select 22 points of chemistry at the 2000-level or higher (excluding CHEM UN2408).

Track 3
CHEM UN1507 Intensive General Chemistry Laboratory
CHEM UN2045 Intensive Organic Chemistry I (Lecture)

CHEM UN2046 Intensive Organic Chemistry II (Lecture)
Select 18 points of chemistry at the 2000-level or higher (excluding CHEM UN2408).

CHEM UN0001 Preparation for College Chemistry. 0 points.
Not for credit toward the bachelor’s degree. Given on a Pass/Fail basis only.

Prerequisites: High school algebra or the instructor’s permission. Recommended preparation: high school physics and chemistry. This course is preparation for Chemistry UN1403 or the equivalent, as well as for other science courses. It is intended for students who have not attended school for sometime or who do not have a firm grasp of high school chemistry. Topics include inorganic nomenclature, chemical reactions, chemical bonding and its relation to molecular structure, stoichiometry, periodic properties of elements, chemical equilibrium, gas laws, acids and bases, and electrochemistry.

Fall 2020: CHEM UN0001

Course Number Section/Call Times/Location Instructor Points Enrollment
CHEM 0001 001/10925 T Th 6:10pm - 7:25pm Room TBA Luis Avila 0 0/50

Fall 2019

CHEM UN1403 General Chemistry I (Lecture). 4 points.
CC/NS: Partial Fulfillment of Science Requirement
Corequisites: MATH UN1101
Preparation equivalent to one year of high school chemistry is assumed. Students lacking such preparation should plan independent study of chemistry over the summer or take CHEM UN0001 before taking CHEM UN1403. Topics include stoichiometry, states of matter, nuclear properties, electronic structures of atoms, periodic properties, chemical bonding, molecular geometry, introduction to quantum mechanics and atomic theory, introduction to organic and biological chemistry, solid state and materials science, polymer science and macromolecular structures and coordination chemistry. Although CHEM UN1403 and CHEM UN1404 are separate courses, students are expected to take both terms sequentially. The order of presentation of topics may differ from the order presented here, and from year to year. Students must ensure they register for the recitation that corresponds to the lecture section. Please check the Directory of Classes for details.

Spring 2020: CHEM UN1403

Course Number Section/Call Times/Location Instructor Points Enrollment
CHEM 1403 001/11594 T Th 6:10pm - 7:25pm 309 Havemeyer Hall Luis Avila 4 80/132

Fall 2020: CHEM UN1403

Course Number Section/Call Times/Location Instructor Points Enrollment
CHEM 1403 001/10910 M W 10:10am - 11:25am Room TBA Gerard Parlin 4 0/230
CHEM 1403 002/10835 T Th 10:10am - 11:25am Room TBA Xavier Roy 0 0/190
CHEM 1403 003/10832 T Th 6:10pm - 7:25pm Room TBA Ruben Savitzky 4 0/190
CHEM 1403 004/10833 M W 6:10pm - 7:25pm Room TBA Robert Beer 0 0/132
Corequisites: CHEM UN1403, CHEM UN1404

An introduction to basic lab techniques of modern experimental chemistry, including quantitative procedures and chemical analysis. Students must register for a Lab Lecture section for this course (CHEM UN1501). Please check the Directory of Classes for details. Please note that CHEM UN1500 is offered in the fall and spring semesters. Mandatory lab check-in will be held during the first week of classes in both the fall and spring semesters.

**CHEM UN1500 General Chemistry Laboratory. 3 points.**
CC/GS: Partial Fulfillment of Science Requirement
Lab Fee: $140.

Prerequisites: CHEM UN1604 or CHEM UN2045
Corequisites: CHEM UN2045
A student-centered experimental course intended for students who are taking or have completed CHEM UN1604 (Second Semester General Chemistry Intensive Lecture offered in Fall), CHEM UN2045 (Intensive Organic Chemistry offered in Fall), or CHEM UN2046 (Intensive Organic Chemistry Lecture offered in Spring). The course will provide an introduction to theory and practice of modern experimental chemistry in a contextual, student-centered collaborative learning environment. This course differs from CHEM UN1500 in its pedagogy and its emphasis on instrumentation and methods. Students must also attend the compulsory Mentoring Session. Please check the Directory of Classes for details. Please note that CHEM UN1507 is offered in the fall and spring semesters.

**CHEM UN1507 Intensive General Chemistry Laboratory. 3 points.**
CC/GS: Partial Fulfillment of Science Requirement
Lab Fee: $140.

Prerequisites: CHEM UN1604 or CHEM UN2045
Corequisites: CHEM UN2045
A student-centered experimental course intended for students who are taking or have completed CHEM UN1604 (Second Semester General Chemistry Intensive Lecture offered in Fall), CHEM UN2045 (Intensive Organic Chemistry offered in Fall), or CHEM UN2046 (Intensive Organic Chemistry Lecture offered in Spring). The course will provide an introduction to theory and practice of modern experimental chemistry in a contextual, student-centered collaborative learning environment. This course differs from CHEM UN1500 in its pedagogy and its emphasis on instrumentation and methods. Students must also attend the compulsory Mentoring Session. Please check the Directory of Classes for details. Please note that CHEM UN1507 is offered in the fall and spring semesters.

**CHEM UN1604 Intensive General Chemistry (Lecture). 4 points.**
CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: Acceptable performance on the Department placement exam during orientation week AND either a grade of "B" or better in CHEM UN1403 or AP chemistry or the equivalent.
Corequisites: MATH UN1102
Topics include chemical kinetics, thermodynamics and chemical bonding. Students must register simultaneously for a corresponding recitation section. Please check Courseworks or contact the instructor or departmental adviser for additional details.

### Spring 2020: CHEM UN1500

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
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<tbody>
<tr>
<td>CHEM 1500</td>
<td>001/11597</td>
<td>M 1:10pm - 4:50pm 302 Havemeyer Hall</td>
<td>Joseph Ulichny, Sarah Hansen</td>
<td>3</td>
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<tr>
<td>CHEM 1500</td>
<td>002/11598</td>
<td>T 1:10pm - 4:50pm 302 Havemeyer Hall</td>
<td>Joseph Ulichny, Sarah Hansen</td>
<td>3</td>
<td>32/46</td>
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<tr>
<td>CHEM 1500</td>
<td>003/11625</td>
<td>T 6:10pm - 9:50pm 302 Havemeyer Hall</td>
<td>Joseph Ulichny, Sarah Hansen</td>
<td>3</td>
<td>49/48</td>
</tr>
<tr>
<td>CHEM 1500</td>
<td>004/11626</td>
<td>W 1:10pm - 4:50pm 302 Havemeyer Hall</td>
<td>Joseph Ulichny, Sarah Hansen</td>
<td>3</td>
<td>50/48</td>
</tr>
<tr>
<td>CHEM 1500</td>
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<td>Th 1:10pm - 4:50pm 302 Havemeyer Hall</td>
<td>Joseph Ulichny, Sarah Hansen</td>
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<tr>
<td>CHEM 1500</td>
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<td>Th 6:10pm - 9:50pm 302 Havemeyer Hall</td>
<td>Joseph Ulichny, Sarah Hansen</td>
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<tr>
<td>CHEM 1500</td>
<td>007/11629</td>
<td>F 8:40am - 12:25pm 302 Havemeyer Hall</td>
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<td>3</td>
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<tr>
<td>CHEM 1500</td>
<td>008/11630</td>
<td>F 1:10pm - 4:50pm 302 Havemeyer Hall</td>
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<td>28/26</td>
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### Spring 2020: CHEM UN1507

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<th>Section/Call Number</th>
<th>Times/Location</th>
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<th>Points</th>
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<tr>
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<td>001/11633</td>
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<td>Luis Avila</td>
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<tr>
<td>CHEM 1507</td>
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<td>F 1:00pm - 6:00pm 302 Havemeyer Hall</td>
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### Fall 2020: CHEM UN1500

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<th>Instructor</th>
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<th>Enrollment</th>
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<td>Joseph Ulichny, Sarah Hansen</td>
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<tr>
<td>CHEM 1500</td>
<td>002/10912</td>
<td>T 6:10pm - 9:50pm 302 Havemeyer Hall</td>
<td>Joseph Ulichny, Sarah Hansen</td>
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<tr>
<td>CHEM 1500</td>
<td>003/10913</td>
<td>W 1:10pm - 4:50pm 302 Havemeyer Hall</td>
<td>Joseph Ulichny, Sarah Hansen</td>
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<td>0/46</td>
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<tr>
<td>CHEM 1500</td>
<td>004/10914</td>
<td>Th 1:10pm - 4:50pm 302 Havemeyer Hall</td>
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### Fall 2020: CHEM UN1507

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<th>Course Number</th>
<th>Section/Call Number</th>
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<th>Points</th>
<th>Enrollment</th>
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<tbody>
<tr>
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<td>001/10926</td>
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<td>Luis Avila</td>
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<td>0/18</td>
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<tr>
<td>CHEM 1507</td>
<td>002/10927</td>
<td>F 1:00pm - 6:00pm 302 Havemeyer Hall</td>
<td>Luis Avila</td>
<td>3</td>
<td>0/18</td>
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</table>

### CHEM UN1604 Intensive General Chemistry (Lecture). 4 points.
CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: Acceptable performance on the Department placement exam during orientation week AND either a grade of "B" or better in CHEM UN1403 or AP chemistry or the equivalent.

Corequisites: MATH UN1102
Topics include chemical kinetics, thermodynamics and chemical bonding. Students must register simultaneously for a corresponding recitation section. Please check Courseworks or contact the instructor or departmental adviser for additional details.

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
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<th>Enrollment</th>
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<tr>
<td>CHEM 1604</td>
<td>001/12207</td>
<td>Th 11:40am - 12:55pm Room TBA</td>
<td>Ann McDermott</td>
<td>4</td>
<td>0/120</td>
</tr>
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</table>
CHEM UN2045 Intensive Organic Chemistry I (Lecture). 4 points.
Prerequisites: A grade of 5 on the Chemistry Advanced Placement exam and an acceptable grade on the Department placement exam or an acceptable grade in CHEM UN1604.
Corequisites: CHEM UN1507
Premedical students may take CHEM UN2045, CHEM UN2046, CHEM UN1507 and CHEM UN2545 to meet the minimum requirements for admission to medical school. This course covers the same material as CHEM UN2443-CHEM UN2444, but is intended for students who have learned the principles of general chemistry in high school or have completed CHEM UN1604 in their first year at Columbia. First year students enrolled in CHEM UN2045-CHEM UN2046 are expected to enroll concurrently in CHEM UN1507. Although CHEM UN2443 and CHEM UN2046 are separate courses, students are expected to take both terms sequentially. A recitation section is required. Please check the Directory of Classes for details and also speak with the TA for the course.

<table>
<thead>
<tr>
<th>Fall 2020: CHEM UN2045</th>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
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<tr>
<td>CHEM 2045</td>
<td>001/10930</td>
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<td>Room TBA</td>
<td>Luis Campos</td>
<td>4</td>
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</table>

CHEM UN2443 Organic Chemistry I (Lecture). 4 points.
Prerequisites: CHEM UN1403 and CHEM UN1404 or CHEM UN1604
The principles of organic chemistry. The structure and reactivity of organic molecules are examined from the standpoint of modern theories of chemistry. Topics include stereochemistry, reactions of organic molecules, mechanisms of organic reactions, syntheses and degradations of organic molecules, and spectroscopic techniques of structure determination. Although CHEM UN2443 and CHEM UN2444 are separate courses, students are expected to take both terms sequentially. Students must ensure they register for the recitation which corresponds to the lecture section. Please check the Directory of Classes for details.

<table>
<thead>
<tr>
<th>Fall 2020: CHEM UN2443</th>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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<tbody>
<tr>
<td>CHEM 2443</td>
<td>001/11032</td>
<td>M W 11:40am - 12:55pm</td>
<td>Room TBA</td>
<td>Karen Phillips</td>
<td>4</td>
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<tr>
<td>CHEM 2443</td>
<td>002/11841</td>
<td>T Th 1:10pm - 2:25pm</td>
<td>Room TBA</td>
<td>Virginia Canalis</td>
<td>4</td>
<td>0/190</td>
</tr>
<tr>
<td>CHEM 2443</td>
<td>003/11033</td>
<td>M W 6:10pm - 7:25pm</td>
<td>Room TBA</td>
<td>Charles Doolan</td>
<td>4</td>
<td>0/120</td>
</tr>
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</table>

CHEM UN2493 Organic Chemistry Laboratory I (Techniques). 0 points.
Lab Fee: $63.00
Prerequisites: (CHEM UN1403 and CHEM UN1404) or (CHEM UN1604) and (CHEM UN1500 or CHEM UN1507)
Corequisites: CHEM UN2443
Techniques of experimental organic chemistry, with emphasis on understanding fundamental principles underlying the experiments in methodology of solving laboratory problems involving organic molecules. Attendance at the first lab lecture and laboratory session is mandatory. Please note that CHEM UN2493 is the first part of a full year organic chemistry laboratory course. Students must register for the lab lecture section (CHEM UN2495) which corresponds to their lab section. Students must attend ONE lab lecture and ONE lab section every other week. Please contact your advisers for further information.

<table>
<thead>
<tr>
<th>Fall 2020: CHEM UN2493</th>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Locaiton</th>
<th>Instructor</th>
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<tbody>
<tr>
<td>CHEM 2493</td>
<td>001/11875</td>
<td>M 1:10pm - 5:00pm</td>
<td>202a Havemeyer Hall</td>
<td>Talha Siddiqui</td>
<td>0</td>
<td>0/24</td>
</tr>
<tr>
<td>CHEM 2493</td>
<td>002/11876</td>
<td>T 12:00pm - 3:50pm</td>
<td>202a Havemeyer Hall</td>
<td>Talha Siddiqui</td>
<td>0</td>
<td>0/24</td>
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<tr>
<td>CHEM 2493</td>
<td>003/11878</td>
<td>T 6:10pm - 10:00pm</td>
<td>202a Havemeyer Hall</td>
<td>Talha Siddiqui</td>
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<td>0/24</td>
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<tr>
<td>CHEM 2493</td>
<td>004/11879</td>
<td>W 1:10pm - 5:00pm</td>
<td>202a Havemeyer Hall</td>
<td>Anna Ghurbanyan</td>
<td>0</td>
<td>0/34</td>
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<tr>
<td>CHEM 2493</td>
<td>005/12533</td>
<td>Th 12:00pm - 3:50pm</td>
<td>202a Havemeyer Hall</td>
<td>Anna Ghurbanyan</td>
<td>0</td>
<td>0/34</td>
</tr>
<tr>
<td>CHEM 2493</td>
<td>006/12534</td>
<td>F 12:00pm - 3:50pm</td>
<td>202a Havemeyer Hall</td>
<td>Anna Ghurbanyan</td>
<td>0</td>
<td>0/34</td>
</tr>
<tr>
<td>CHEM 2493</td>
<td>007/11880</td>
<td>M 1:10pm - 5:00pm</td>
<td>202a Havemeyer Hall</td>
<td>Talha Siddiqui</td>
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<td>0/24</td>
</tr>
<tr>
<td>CHEM 2493</td>
<td>008/11881</td>
<td>T 12:00pm - 3:50pm</td>
<td>202a Havemeyer Hall</td>
<td>Talha Siddiqui</td>
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<td>0/24</td>
</tr>
<tr>
<td>CHEM 2493</td>
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<td>T 6:10pm - 10:00pm</td>
<td>202a Havemeyer Hall</td>
<td>Talha Siddiqui</td>
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<tr>
<td>CHEM 2493</td>
<td>010/11883</td>
<td>W 1:10pm - 5:00pm</td>
<td>202a Havemeyer Hall</td>
<td>Anna Ghurbanyan</td>
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<td>0/34</td>
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<tr>
<td>CHEM 2493</td>
<td>011/12535</td>
<td>Th 12:00pm - 3:50pm</td>
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<td>Anna Ghurbanyan</td>
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<tr>
<td>CHEM 2493</td>
<td>012/12536</td>
<td>F 12:00pm - 3:50pm</td>
<td>202a Havemeyer Hall</td>
<td>Anna Ghurbanyan</td>
<td>0</td>
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</table>

CHEM UN2545 Intensive Organic Chemistry Laboratory. 3 points.
Lab Fee: $125.
Prerequisites: CHEM UN2045 and CHEM UN2046 and CHEM UN1507
The lab is intended for students who have taken Intensive Organic Chemistry, CHEM UN2045 - CHEM UN2046 and who intend to major in Chemistry, Biochemistry, Chemical Physics, or Environmental Chemistry.

<table>
<thead>
<tr>
<th>Fall 2020: CHEM UN2545</th>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Locaiton</th>
<th>Instructor</th>
<th>Points</th>
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<tbody>
<tr>
<td>CHEM 2545</td>
<td>001/10932</td>
<td>M 1:00pm - 6:00pm</td>
<td>202a Havemeyer Hall</td>
<td>Fay Ng</td>
<td>3</td>
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<tr>
<td>CHEM 2545</td>
<td>002/10933</td>
<td>T 1:00pm - 6:00pm</td>
<td>202a Havemeyer Hall</td>
<td>Fay Ng</td>
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<td>0/10</td>
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</table>
CHEM UN3079 Physical Chemistry I. 4 points.
Prerequisites: (CHEM UN1403 and CHEM UN1404) or (CHEM UN1604) or (CHEM UN2045 and CHEM UN2046) and (MATH UN1101 and MATH UN1102) or (MATH UN1207 and MATH UN1208) and (PHYS UN1401 and PHYS UN1402) PHYS UN1201 - PHYS UN1202 is acceptable; PHYS UN1401 - PHYS UN1402 or the equivalent is HIGHLY recommended. Corequisites: CHEM UN3085
Elementary, but comprehensive, treatment of the fundamental laws governing the behavior of individual atoms and molecules and collections of them. CHEM UN3079 covers the thermodynamics of chemical systems at equilibrium and the chemical kinetics of nonequilibrium systems. Although CHEM UN3079 and CHEM UN3080 are separate courses, students are expected to take both terms sequentially. A recitation section is required. Please check the Directory of Classes for details and also speak with the TA for the course.

Fall 2020: CHEM UN3079
<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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<tr>
<td>CHEM 3079</td>
<td>001/11073</td>
<td>M W 10:10am - 11:25am Room TBA</td>
<td>Timothy Berkelbach</td>
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CHEM UN3085 Physical and Analytical Chemistry Laboratory I. 4 points.
Lab Fee: $125 per term.

Corequisites: CHEM UN3079
A student-centered experimental course intended for students who are co-registered or have completed CHEM UN3079 and CHEM UN3080. The course emphasizes techniques of experimental physical chemistry and instrumental analysis, including vibrational, electronic, and laser spectroscopy; electroanalytical methods; calorimetry; reaction kinetics; hydrodynamic methods; scanning probe microscopy; applications of computers to reduce experimental data; and computational chemistry. Students must also attend the compulsory Mentoring Session. Please check the Directory of Classes for details.

Fall 2020: CHEM UN3085
<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
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<td>001/10928</td>
<td>T 12:00pm - 6:00pm 222 Havemeyer Hall</td>
<td>Luis Avila</td>
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CHEM UN3098 Supervised Independent Research. 4 points.
Lab Fee: $105 per term.

Prerequisites: the instructor’s permission for entrance, and the departmental representative’s permission for aggregate points in excess of 12 or less than 4.
This course may be repeated for credit (see major and concentration requirements). Individual research under the supervision of a member of the staff. Research areas include organic, physical, inorganic, analytical, and biological chemistry. Please note that CHEM UN3098 is offered in the fall and spring semesters.

Spring 2020: CHEM UN3098
<table>
<thead>
<tr>
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<td>Vesna Gasperov</td>
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Fall 2020: CHEM UN3098
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BIOC UN3300 Biochemistry. 3 points.
Prerequisites: one year each of Introductory Biology and General Chemistry. Corequisites: Organic Chemistry. Primarily aimed at nontraditional students and undergraduates who have course conflicts with BIOC UN3501.
Biochemistry is the study of the chemical processes within organisms that give rise to the immense complexity of life. This complexity emerges from a highly regulated and coordinated flow of chemical energy from one biomolecule to another. This course serves to familiarize students with the spectrum of biomolecules (carbohydrates, lipids, amino acids, nucleic acids, etc.) as well as the fundamental chemical processes (glycolysis, citric acid cycle, fatty acid metabolism, etc.) that allow life to happen. In particular, this course will employ active learning techniques and critical thinking problem-solving to engage students in answering the question: how is the complexity of life possible? NOTE: While Organic Chemistry is listed as a corequisite, it is highly recommended that you take Organic Chemistry beforehand.

Spring 2020: BIOC UN3300
<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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<tr>
<td>BIOC 3300</td>
<td>001/11855</td>
<td>T 7:10pm - 9:30pm 717 Hamilton Hall</td>
<td>Danny Ho</td>
<td>3</td>
<td>67/100</td>
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BIOC UN3501 Biochemistry: Structure and Metabolism. 4 points.
Prerequisites: one year of BIOL UN2005 and BIOL UN2006 and one year of organic chemistry.
Lecture and recitation. Students wishing to cover the full range of modern biochemistry should take both BIOC UN3501 and BIOC UN3512. UN3501 covers subject matters in modern biochemistry, including chemical biology and structural biology, discussing the structure and function of both proteins and small molecules in biological systems. Proteins are the primary class of biological macromolecules and serve to carry out most cellular functions. Small organic molecules function in energy production and creating building blocks for the components of cells and can also be used to perturb the functions of proteins directly. The first half of the course covers protein structure, enzyme kinetics and enzyme mechanism. The second half of the course explores how small molecules are used endogenously by living systems in metabolic and catabolic pathways; this part of the course focuses on mechanistic organic chemistry involved in metabolic pathways.

CHEM UN3920 Senior Seminar in Chemical Research. 2 points.
Pass/Fail credit only.
Open to senior chemistry, biochemistry, environmental chemistry, and chemical physics majors; senior chemistry concentrators; and students who have taken or are currently enrolled in CHEM UN3098. Senior seminar provides direct access to modern chemical research through selected studies by the students from active fields of chemical research. Topics to be presented and discussed draw from the current scientific literature and/or UN3098 research.

Fall 2020: CHEM UN3920
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<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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<tbody>
<tr>
<td>CHEM 3920</td>
<td>001/10931</td>
<td>F 2:10pm - 4:00pm 711 Havemeyer Hall</td>
<td>Karen Phillips</td>
<td>2</td>
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</table>
CHEM GU4071 Inorganic Chemistry. 4.5 points.
CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: (CHEM UN1403 and CHEM UN1404) or (CHEM UN1604) or (CHEM UN2045 and CHEM UN2046), or the equivalent.

Principles governing the structure and reactivity of inorganic compounds surveyed from experimental and theoretical viewpoints. Topics include inorganic solids, aqueous and nonaqueous solutions, the chemistry of selected main group elements, transition metal chemistry, metal clusters, metal carbonyls, and organometallic chemistry, bonding and resonance, symmetry and molecular orbitals, and spectroscopy.

Fall 2020: CHEM GU4071
Course Number: 001/11026
Times/Location: M W 8:40am - 9:55am
Instructor: Jonathan
Points: 4.5
Enrollment: 0/42

CHEM GU4147 Advanced Organic Chemistry. 4.5 points.
Prerequisites: elementary organic and physical chemistry.
The mechanisms of organic reactions, structure of organic molecules, and theories of reactivity. How reactive intermediates are recognized and mechanisms are deduced using kinetics, stereochemistry, isotopes, and physical measurements.

Fall 2020: CHEM GU4147
Course Number: 001/11027
Times/Location: T Th 10:10am - 11:25am
Instructor: Jack Norton
Points: 4.5
Enrollment: 0/42

CHEM GU4148 Synthesis Methods in Organic Chemistry I. 4.5 points.
Prerequisites: Organic chemistry.
This course is intended for graduate students and advanced undergraduate students. The main purpose of the course is to introduce students to modern synthetic chemistry via the selected series of topics (synthetic planning and the logic of organic assembly, classical and new reactions/methods and their use in complex target syntheses). Mechanistic underpinning of the discussed reaction processes will also be briefly discussed. For each module (see the content below), specific examples of syntheses of natural products and/or synthetic materials will be provided. In addition to lectures, students will select and present relevant papers in the class (the number of student symposia will depend on the final enrollment in this course). The basic knowledge of transition metal chemistry is recommended for the cross-coupling reactions (i.e., structure, electron counting, and elemental reaction types of transition metals).

Fall 2020: CHEM GU4148
Course Number: 001/11028
Times/Location: M W 10:10am - 11:25am
Instructor: Dalibor Sames, James Leighton
Points: 4.5
Enrollment: 0/42

CHEM GU4221 Quantum Chemistry. 4.5 points.
Prerequisites: elementary physical chemistry.
Basic quantum mechanics: the Schrodinger equation and its interpretation, exact solutions in simple cases, methods or approximation, angular Momentum and electronic spin, and an introduction to atomic and molecular structure.

Fall 2020: CHEM GU4221
Course Number: 001/11029
Times/Location: M W 11:40am - 12:55pm
Instructor: Milan Deler
Points: 4.5
Enrollment: 0/42

CHEM GU4230 Statistical Mechanics. 4.5 points.
Prerequisites: elementary physical chemistry.
Corequisites: CHEM G4221.
Topics include the classical and quantum statistical mechanics of gases, liquids, and solids.

Fall 2020: CHEM GU4230
Course Number: 001/11030
Times/Location: T Th 11:40am - 12:55pm
Instructor: Bruce Berne
Points: 4.5
Enrollment: 0/42

BIOC GU4323 Biophysical Chemistry I. 4 points.
Prerequisites: (CHEM UN2443 and CHEM UN2444) and (CHEM UN3079 and CHEM UN3080) and (BIOC UN3501), or the equivalent.
Development and application of chemical methods for understanding the molecular mechanisms of cellular processes. Review of the biosynthesis, chemical synthesis, and structure and function of proteins and nucleic acids. Application of chemical methods--including structural biology, enzymology, chemical genetics, and the synthesis of modified biological molecules--to the study of cellular processes--including transcription, translation, and signal transduction.

Fall 2020: BIOC GU4323
Course Number: 001/11840
Times/Location: M W 1:10pm - 2:25pm
Instructor: Virginia Comish
Points: 4.0
Enrollment: 0/42

BIOC GU4324 Biophysical Chemistry II. 4 points.
This course provides a rigorous introduction to the theory underlying widely used biophysical methods, which will be illustrated by practical applications to contemporary biomedical research problems. The course has two equally important goals. The first goal is to explicate the fundamental approaches used by physical chemists to understand the behavior of molecules and to develop related analytical tools. The second goal is to prepare students to apply these methods themselves to their own research projects. The course will be divided into seven modules: (i) solution thermodynamics; (ii) hydrodynamic methods; (iii) statistical analysis of experimental data; (iv) basic quantum mechanics; (v) optical spectroscopy with an emphasis on fluorescence; (vi) nuclear magnetic resonance spectroscopy; and (vii) light-scattering and diffraction methods. The first three modules will be covered during the fall term. In each module, the underlying physical theories and models will be presented and used to derive the mathematical equations applied to the analysis of experimental data. Weekly recitations will emphasize the analysis of real experimental data and understanding the applications of biophysical experimentation in published research papers.
## Spring 2020

### CHEM UN1403 General Chemistry I (Lecture). 4 points.
CC/GS: Partial Fulfillment of Science Requirement

Corequisites: MATH UN1101
Preparation equivalent to one year of high school chemistry is assumed. Students lacking such preparation should plan independent study of chemistry over the summer or take CHEM UN0001 before taking CHEM UN1403. Topics include stoichiometry, states of matter, nuclear properties, electronic structures of atoms, periodic properties, chemical bonding, molecular geometry, introduction to quantum mechanics and atomic theory, introduction to organic and biological chemistry, solid state and materials science, polymer science and macromolecular structures and coordination chemistry. Although CHEM UN1403 and CHEM UN1404 are separate courses, students are expected to take both terms sequentially. The order of presentation of topics may differ from the order presented here, and from year to year. Students must ensure they register for the recitation that corresponds to the lecture section. Please check the Directory of Classes for details.

### CHEM UN1404 General Chemistry II (Lecture). 4 points.
CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: CHEM UN1403
Although CHEM UN1403 and CHEM UN 1404 are separate courses, students are expected to take both terms sequentially. Topics include gases, kinetic theory of gases, states of matter: liquids and solids, chemical equilibria, applications of equilibrium, acids and bases, chemical thermodynamics, energy, enthalpy, entropy, free energy, periodic properties, chemical kinetics, and electrochemistry. The order of presentation of topics may differ from the order presented here, and from year to year. Students must ensure they register for the recitation that corresponds to the lecture section. Please check the Directory of Classes for details.

### CHEM UN1500 General Chemistry Laboratory. 3 points.
CC/GS: Partial Fulfillment of Science Requirement
Lab Fee: $140.

Corequisites: CHEM UN1403, CHEM UN1404
An introduction to basic lab techniques of modern experimental chemistry, including quantitative procedures and chemical analysis. Students must register for a Lab Lecture section for this course (CHEM UN1501). Please check the Directory of Classes for details. Please note that CHEM UN1500 is offered in the fall and spring semesters. Mandatory lab check-in will be held during the first week of classes in both the fall and spring semesters.
CHEM UN1507 Intensive General Chemistry Laboratory.  3 points.
CC/GS: Partial Fulfillment of Science Requirement
Lab Fee: $140.

Prerequisites: CHEM UN1604 or CHEM UN2045
Corequisites: CHEM UN2045
A student-centered experimental course intended for students who are
taking or have completed CHEM UN1604 (Second Semester General
Chemistry Intensive Lecture offered in Fall), CHEM UN2045 (Intensive
Organic Chemistry offered in Fall), or CHEM UN2046 (Intensive Organic
Chemistry Lecture offered in Spring). The course will provide an
introduction to theory and practice of modern experimental chemistry
in a contextual, student-centered collaborative learning environment.
This course differs from CHEM UN1500 in its pedagogy and its emphasis
on instrumentation and methods. Students must also attend the
compulsory Mentoring Session. Please check the Directory of Classes for
details. Please note that CHEM UN1507 is offered in the fall and spring
semesters.

Spring 2020: CHEM UN1507
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CHEM UN2046 Intensive Organic Chemistry II (Lecture).  4 points.
Prerequisites: CHEM UN2045
Premedical students may take CHEM UN2045, CHEM UN2046, and CHEM
UN2545 to meet the minimum requirements for admission to medical
school. This course covers the same material as CHEM UN2443 - CHEM
UN2444, but is intended for students who have learned the principles of
general chemistry in high school OR have completed CHEM UN1604 in
their first year at Columbia. First year students enrolled in CHEM UN2045
- CHEM UN2046 are expected to enroll concurrently in CHEM UN1507.
Although CHEM UN2045 and CHEM UN2046 are separate courses, students are expected to take both terms sequentially. A recitation
section is required. Please check the Directory of Classes for details and
also speak with the TA for the course.

Spring 2020: CHEM UN2046
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CHEM UN2444 Organic Chemistry II (Lecture).  4 points.
Prerequisites: CHEM UN1404 or CHEM UN1604 and CHEM UN1500 and
CHEM UN2443
The principles of organic chemistry. The structure and reactivity
of organic molecules are examined from the standpoint of modern
theories of chemistry. Topics include stereochemistry, reactions of
organic molecules, mechanisms of organic reactions, syntheses and
degradations of organic molecules, and spectroscopic techniques of
structure determination. Although CHEM UN2443 and CHEM UN2444 are
separate courses, students are expected to take both terms sequentially.
Students must ensure they register for the recitation which corresponds
to the lecture section. Please check the Directory of Classes for details.

Spring 2020: CHEM UN2444
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CHEM UN2408 First-Year Seminar in Chemical Research.  1 point.
Prerequisites: CHEM UN1403 or CHEM UN1604 or CHEM UN2045 or the
instructor's permission.
A one-hour weekly lecture, discussion, and critical analysis of topics that
reflect problems in modern chemistry, with emphasis on current areas of
active chemical research.

Spring 2020: CHEM UN2408
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<th>Course Number</th>
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<td>Gasperov</td>
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</table>
CHEM UN2494 Organic Chemistry Laboratory II (Synthesis). 1.5 point.
Lab Fee: $62.00

Prerequisites: (CHEM UN1403 and CHEM UN1404) and CHEM UN1500 and CHEM UN2493
Corequisites: CHEM UN2444
Please note that you must complete CHEM UN2493, or the equivalent, before you register for CHEM UN2494. This lab introduces students to experimental design and trains students in the execution and evaluation of scientific data. The technique experiments in the first half of the course (CHEM UN2493) teach students to develop and master the required experimental skills to perform the challenging synthesis experiments in the second semester. The learning outcomes for this lab are the knowledge and experimental skills associated with the most important synthetic routes widely used in industrial and research environments. Attendance at the first lab lecture and laboratory session is mandatory. Please note that CHEM UN2494 is the second part of a full year organic chemistry laboratory course. Students must register for the lab lecture section (CHEM UN2496) which corresponds to their lab section. Students must attend ONE lab lecture and ONE lab section every other week. Please contact your advisers for further information.

Spring 2020: CHEM UN2494

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<th>Course Number</th>
<th>Section/Call Number</th>
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CHEM UN3080 Physical Chemistry II. 4 points.
Prerequisites: CHEM UN3079
Corequisites: CHEM UN3086
CHEM UN3080 covers the quantum mechanics of atoms and molecules, the quantum statistical mechanics of chemical systems, and the connection of statistical mechanics to thermodynamics. Although CHEM UN3079 and CHEM UN3080 are separate courses, students are expected to take both terms sequentially. A recitation section is required. Please check the Directory of Classes for details and also speak with the TA for the course.

Spring 2020: CHEM UN3080

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CHEM UN3086 Physical and Analytical Chemistry Laboratory II. 4 points.
Lab Fee: $125 per term.

Prerequisites: CHEM UN3085, CHEM UN3080 is acceptable corequisite for CHEM UN3086.
A student-centered experimental course intended for students who are co-registered or have complete CHEM UN3079 and CHEM UN3080. The course emphasizes techniques of experimental physical chemistry and instrumental analysis, including vibrational, electronic, and laser spectroscopy; electroanalytical methods; calorimetry, reaction kinetics; hydrodynamic methods; scanning probe microscopy; applications of computers to reduce experimental data; and computational chemistry. Please check the Directory of Classes for details.

Spring 2020: CHEM UN3086

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<th>Course Number</th>
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CHEM UN3098 Supervised Independent Research. 4 points.
Lab Fee: $105 per term.

Prerequisites: the instructor's permission for entrance, and the departmental representative’s permission for aggregate points in excess of 12 or less than 4.
This course may be repeated for credit (see major and concentration requirements). Individual research under the supervision of a member of the staff. Research areas include organic, physical, inorganic, analytical, and biological chemistry. Please note that CHEM UN3098 is offered in the fall and spring semesters.

Spring 2020: CHEM UN3098

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Fall 2020: CHEM UN3098

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<td>T 1:00pm - 6:00pm</td>
<td>Vesna Gasperov</td>
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CHEM UN3546 Advanced Organic Chemistry Laboratory. 3 points.
Laboratory Fee: $125.

Prerequisites: CHEM UN2493 and CHEM UN2494, or the equivalent.
A project laboratory with emphasis on complex synthesis and advanced techniques including qualitative organic analysis and instrumentation.

Spring 2020: CHEM UN3546

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<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
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<td>CHEM 3546</td>
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CHEM GU4102 Chemistry for the Brain. 4.5 points.
This course was upgraded from 2.5 to 4.5 and assigned a new number.
Prerequisites: Organic chemistry and biology courses, neuroscience or neurobiology recommended, but not required.
The study of the brain is one of the most exciting frontiers in science and medicine today. Although neuroscience is by nature a multi-disciplinary effort, chemistry has played many critical roles in the development of modern neuroscience, neuropharmacology, and brain imaging. Chemistry, and the chemical probes it generates, such as molecular modulators, therapeutics, imaging agents, sensors, or actuators, will continue to impact neuroscience on both preclinical and clinical levels. In this course, two major themes will be discussed. In the first one, titled "Imaging brain function with chemical tools," we will discuss molecular designs and functional parameters of widely used fluorescent sensors in neuroscience (calcium, voltage, and neurotransmitter sensors), their impact on neuroscience, pros and cons of genetically encoded sensors versus chemical probes, and translatability of these approaches to the human brain. In the second major theme, titled "Perturbation of the brain function with chemical tools," we will examine psychoactive substances, the basics of medicinal chemistry, brain receptor activation mechanisms and coupled signaling pathways, and their effects on circuit and brain function. We will also discuss recent approaches, failures and successes in the treatment of neurodegenerative and psychiatric disorders. Recent advances in precise brain function perturbation by light (optogenetics and photopharmacology) will also be introduced. In the context of both themes we will discuss the current and future possibilities for the design of novel materials, drawing on the wide molecular structural space (small molecules, proteins, polymers, nanomaterials), aimed at monitoring, modulating, and repairing human brain function. This course is intended for students (undergraduate and graduate) from the science, engineering and medical departments.

CHEM GU4145 NMR Spectroscopy. 1 point.
Prerequisites: elementary organic chemistry.
Introduction to theory and practice of NMR spectroscopy. Instrumental aspects, basic NMR theory, NOE, and a survey of 2D methods are covered.

BIOC GU4512 Molecular Biology. 3 points.
Prerequisites: one year of biology. Recommended but not required: BIOC UN3501.
This is a lecture course designed for advanced undergraduates and graduate students. The focus is on understanding at the molecular level how genetic information is stored within the cell and how it is regulated. Topics covered include genome organization, DNA replication, transcription, RNA processing, and translation. This course will also emphasize the critical analysis of the scientific literature and help students understand how to identify important biological problems and how to address them experimentally. SCE and TC students may register for this course, but they must first obtain the written permission of the instructor, by filing out a paper Registration Adjustment Form (Add/ Drop form). The form can be downloaded at the URL below, but must be signed by the instructor and returned to the office of the registrar. http://registrar.columbia.edu/sites/default/files/content/reg-adjustment.pdf

Courses Offered in Alternate Years

Please contact the Undergraduate Program Manager, Vesna Gasperov (vg2231@columbia.edu), for further information.

CHEM GU4103 Organometallic Chemistry. 4.5 points.
Prerequisites: (CHEM UN2443 and CHEM UN2444), or the equivalent.
Some background in inorganic and physical chemistry is helpful but not required.
Main group and transition metal organometallic chemistry: bonding, structure, reactions, kinetics, and mechanisms.

CHEM GU4104 Structural Methods in Inorganic Chemistry. 2 points.
Not offered during 2019-20 academic year.

The determination of structures by diffraction methods, focusing on single crystal X-ray diffraction, is described. Emphasis is placed on a critical evaluation of published data.

CHEM GU4111 Applications of NMR Spectroscopy To Inorganic Chemistry. 2 points.
The use of multinuclear NMR spectroscopy in the determination of the structures of inorganic molecules and the use of dynamic NMR spectroscopy (variable temperature NMR and magnetization transfer techniques) to provide information concerned with reaction mechanisms.
CHEM GU4154 Chemical Characterization for Synthetic Chemists. 3 points.
Prerequisites: Columbia University's laboratory safety certification is required. One year each of (i) general chemistry lecture/lab; (ii) organic or inorganic chemistry lecture/lab; and (iii) research experience in a chemistry lab are recommended. This course will teach synthetic chemists to use mass spectrometry, analytical chromatography, and single-crystal X-ray diffraction as tools for research in synthetic chemistry. The teaching approach will be practical with an emphasis on hands-on experience. Students will gain: (1) A user-level understanding of the theory of these analytical methods. (2) Hands-on proficiency with a variety of instruments available at Columbia. (3) An introduction to advanced instrument capabilities and an awareness of their applications. (4) Proficiency in processing and interpreting data.

CHEM GU4210 Writing Workshop for Chemists. 1 point.
Prerequisites: recommended for undergraduate students to have taken at least one semester of independent research. This course offers undergraduate and graduate students an introduction to scientific writing and provides an opportunity for them to become more familiar with the skill and craft of communicating complex scientific research. This course will provide students with the basic grammatical, stylistic and practical skills required to write effective academic journal articles, theses, or research proposals. In addition, through an innovative partnership with Columbia University Libraries' Digital Science Center, students will learn how to apply these basic skills to their writing through the use of state-of-the-art software and on-line resources. Regular opportunities to write, peer edit and revise throughout the semester will allow students to put what they are learning into immediate practice. It is recommended that undergraduates have taken at least one semester of research for credit before taking this course. Undergraduates should plan to take this course after taking the required Core course University Writing.

CHEM GR6168 Materials Chemistry IIA. 2.5 points.
Prerequisites: CHEM UN2443, or the equivalent.
This is an introductory course to the emerging field macromolecular materials chemistry. The general topics will be based on the chemistry, self-assembly, and performance of block copolymers and conjugated polymers. Particular emphasis will be devoted to the demands required to drive materials from scientific curiosity to commercialization. At the fundamental level, the course will cover topics on polymerization techniques, electronic structure of organic semiconductors, characterization strategies, nanostructures and self-assembly.

CHEM GR6169 Materials Chemistry IIB. 2.5 points.
Prerequisites: CHEM UN2443, or the equivalent.
This is an introductory course to the field of inorganic nanomaterials chemistry. The course will cover the synthesis, the structural, electronic and magnetic characterization, and the physical properties of zero-, one- and two-dimensional inorganic nanomaterials. Particular emphasis will be devoted to the design of building blocks that can organize into functional assemblies and to the emergence of collective physical properties. The course will also explore the recent and developing electronic and optoelectronic applications of these materials.

CHEM GR6222 Quantum Chemistry II. 2.5 points.
Prerequisites: CHEM GU4221
Atomic and molecular quantum mechanics: fundamentals of electronic structure, many-body wave functions and operators, Hartree-Fock and density functional theory, the Dirac equation.

CHEM GR6231 Intermediate Statistical Mechanics. 2.5 points.
Prerequisites: CHEM GU4221 and CHEM GU4230
Phase transitions and critical phenomena; renormalization group methods; classical theory of fluids.

CHEM GR8106 Kinetics. 2.5 points.
Not offered during 2019-20 academic year.

Kinetics and mechanisms of inorganic reactions.

CHEM GR8120 Polymers in Nanotechnology. 2.5 points.
Polymeric materials have long been ubiquitous items and played important roles in revolutionizing the way we live. Due to the advent of modern polymerization fabrication strategies, polymers are rapidly gaining interest for the development of next generation devices and medical treatment. This course will focus on the chemistry polymers and their use as nanostructured materials created by self-assembly and top-down fabrication techniques. Specifically, the class will be divided into two sections describing the uses of organic nanostructures on a) surfaces and b) as particles. Patterned surfaces will be described in terms of photo-, imprint-, and block copolymer lithography. The preparation of nanoparticles through polymer synthesis, dendrimers, and mechanical manipulation will be the second part.

CHEM GR8223 Quantum Chemistry, III. 2.5 points.
Not offered during 2019-20 academic year.

Prerequisites: CHEM G6222.
Nonlinear spectroscopy: second harmonic and vibrational sum frequency generation; applications to surface and colloidal nano-microparticle interfaces; nonradiative molecular processes.

CHEM GR8232 Advanced Statistical Mechanics. 2.5 points.
Prerequisites: CHEM GU4221 and CHEM GU4230, or their equivalents.
Stochastic processes; Brownian motion; Langevin equations and fluctuation-dissipation theorems; reaction rate theory; time correlation functions and linear response theory.

CHEM GR8349 Research Ethics & Philosophy. 2.5 points.
This lecture course aims to address philosophical and ethical questions in scientific research. What are the most important traits of successful scientists whose discoveries have greatly benefited humanity (and led to Nobel Prizes)? What distinguishes great science from mediocre or pathological "science"? What are the ethical standards of scientific research? How do we identify scientific misconduct or fraud? Why are ethical standards so critical to the integrity of the research enterprise? The course requires extensive participation of students in the form of discussions and debates. Grades will be based on participation, writing assignments, and one oral presentation.

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Chemical Physics