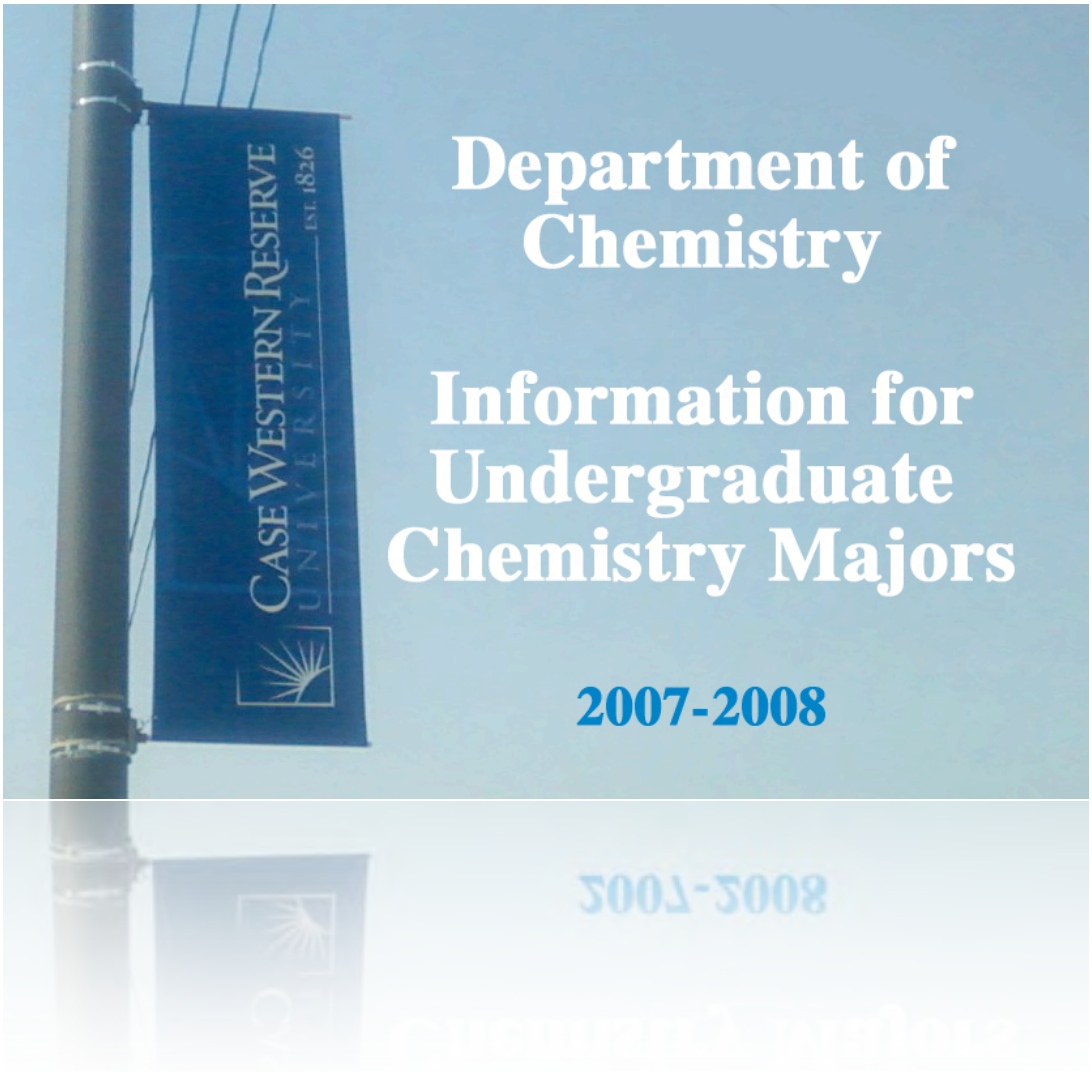



This booklet gives information that is useful to undergraduate students majoring in Chemistry. It has been prepared by the Chemistry Undergraduate Committee. Questions which may arise that are not answered by the material in this booklet can be directed to a member of the Committee, the student's faculty adviser or the Chemistry Office of Student Affairs located in 204 Clapp Hall (phone 368-3621).

In addition to this brochure, information is also available at: http://www.case.edu/artsci/chem

The course requirements for the B.A. and B.S. degrees in Chemistry presented in this booklet apply only to students who entered the University in Fall, 2005 and thereafter, who must fulfill SAGES program requirements. Students who entered or who are not in the SAGES program should obtain a list of the old course requirements from the Academic Affairs Office, Clapp 204.

# Table of Contents


# The Department of Chemistry

***...when I started doing chemistry, I did it the way I fished – for the excitement, the discovery, the adventure, for going after the most elusive catch imaginable in uncharted seas.***

***-Barry K. Sharpless, 2001 Nobel Laureate***

The Department of Chemistry at Case Western Reserve University presently comprises 21 faculty members, approximately 90 graduate students, 15 postdoctoral fellows, 4 senior research associates, and over 110 undergraduate majors, with supporting technical, administrative and secretarial staffs. The Department of Chemistry is located in two adjacent buildings, Clapp Hall, built in 2001, and the John Schoff Millis Science Center, built in 1962 (and renovated 2001). Linked with DeGrace Hall (Biology) by a gorgeous glass atrium and meeting space, these buildings comprise the Agnar Pytte Center for Science Education and Research at CWRU. Both contain air-conditioned offices, classrooms, and instructional and research laboratories engineered for safety. A well-inventoried stockroom is maintained in the Millis Building.

The department stands at the center of a broad range of cooperative activities in chemical science at Case Western Reserve University involving numerous additional departments, including those within the adjacent Engineering and Medical Schools.


# Advisors for Chemistry

Students who have decided to become a chemistry major should obtain the necessary paperwork from either the Office of Undergraduate Studies or the Chemistry Academic Affairs Office (in Clapp 204).

After a student has declared a chemistry major, he or she is assigned a chemistry adviser by the Chemistry Department. This faculty member remains the student's advisor until graduation (unless the student requests a new advisor within the chemistry department), and should be contacted each semester regarding scheduling, and at any other time when problems or questions arise. Faculty advisers are assigned in 207 Clapp Hall by the Associate Chair of Chemistry.

***Whereas interdisciplinary study and research are essential and provide much of the most significant and intriguing advances, they cannot and should not be pursued without building on solid fundamentals. There can be no substitute to first acquiring solid foundations in the basic underlying disciplines of mathematics, physics, and chemistry. Would a high-rise building be stable if construction started at its higher levels, lacking solid foundations?***

***- George Olah, Nobel Laureate 1994, and Chair of Chemistry CWRU 1967-1969***


# Programs in Chemistry

The following sections describe the two Chemistry Major Programs. The first of these programs is the **Bachelor of Arts in Chemistry**, a very flexible curriculum designed to give a student solid background in chemistry, and at the same time, allow students to undertake other CWRU disciplinary studies (often receiving minors), or as is very popular, allowing students to get double majors. The BA in chemistry has traditionally been very popular with students interested in eventually applying to professional schools after graduation, especially for students considering medical, dental, and law schools (etc.). The depth of knowledge in Chemistry, however, is still sufficient such that application to graduate programs in Chemistry or its allied fields is still open to the student. In addition, the Teacher Licensure program (see page 23) lets students get accreditation to become high school teachers.

The **Bachelor of Science in Chemistry** provides a rigorous study of Chemistry for the student who desires to become a professional chemist. The B.S. program prepares the student for entry into graduate programs in Chemistry leading to advanced degrees (MS or PhD) or for direct entry into the job market at the baccalaureate level.

In addition to the specific department requirements of the Chemistry BA or BS degree, there are requirements from the University (SAGES and PE) and the College of Arts & Sciences (CAS GER) that must be fulfilled to earn your degree. *Some* of this information is summarized below.

**SAGES Requirement Overview** (please see UG Studies Office for complete details)

1. First Seminar (4 credits)
2. University Seminars (2 courses, 3 credits each)
3. Departmental Seminar (3 or 4 credits)*
4. SAGES Capstone (3-6 credits)**
5. University Composition Requirement

**University Composition Requirement** (zero credit assembly of final graded writing assignments from First Seminar and University Seminar Courses that makes your Writing Portfolio).

**Physical Education Requirement** (2 full semesters at zero credits).

**CAS General Education Requirements**
Breadth Requirements (18 credit hour-six 3 or 4 credit hr courses) distributed as follows:

Arts & Humanities (6-8), Natural and Mathematical Sciences (6-8), Social Sciences (6), Quantitative Reasoning (3-4), Global and Cultural Diversity (3-4)

***Please see UG Studies and your Degree Progress Report (DPR) to follow progress towards completion of all requirements for the degree(s) you are seeking.***

**Notes**:

*Students majoring in Chemistry will automatically fulfill their SAGES Departmental Seminar course requirement by taking the required Chemistry course CHEM 305 (BA majors) or CHEM 332 (BS majors).

**All students must complete a capstone experience. Chemistry students may elect to take CHEM 398 or a capstone experience in another department. Students seeking more than one major DO NOT have to complete more than one SAGES capstone experience.

# B.A. in Chemistry

*Required Departmental Courses*

| Course | Credits |
|---|---|
| *CHEM 105* | *3* |
| *CHEM 106* | *3* |
| *CHEM 113* | *2* |
| *CHEM 223 or 323* | *3* |
| *CHEM 224 or 324* | *3* |
| *CHEM 233* | *2* |
| *CHEM 234 or 322 (3)* | *2 (3)* |
| *CHEM 301 or 335* | *3* |
| *CHEM 302 or 336* | *3* |
| *CHEM 304* | *4* |
| *CHEM 305** | *3* |
| *TOTAL* | *31 (32)* |

*Additional Required Courses*

| Course | Credits |
|---|---|
| *MATH 125 or 121* | *4* |
| *MATH 126 or 122* | *4* |
| *PHYS 115* | *4* |
| *PHYS 116* | *4* |
| *TOTAL* | *16* |

*Summary*

| Component | Credits |
|---|---|
| *SAGES (17), CAS GER (18)* | *35*** |
| *Chemistry* | *31 (32)* |
| *Other Required Courses* | *16* |
| *Open Electives* | *varies-to make 120**** |
| *TOTAL* | *120* |

**Notes**:

*The required Chemistry course CHEM 305 is an approved SAGES Departmental Seminar-no other course is needed.
** Due to overlap in requirements in departmental seminar CHEM 305, this number is reduced by 3 credits. In addition, this total number is further reduced as two courses from your required courses can also be used to fulfill CAS GER breadth requirements in Natural and Mathematical Sciences.
***Open electives will vary depending if you have minors, second major, or are in the Teacher Licensure program.

*B.A. in Chemistry, Recommended Sequence for required Science and Math Courses*

B.A. in Chemistry

| Fall Semester<br>Class/Lab/Credit Hours | Spring Semester<br>Class/Lab/Credit Hours |
|---|---|
| *First Year*<br><br>*CHEM 105 Principles of Chem. I (3-0-3)*<br>*CHEM 113 Principles of Chem. Lab (1-3-2)*<br>*MATH 125 Mathematics I (4-0-4)* | *First Year*<br><br>*CHEM 106 Principles of Chem. II (3-0-3)*<br>*MATH 126 Mathematics II (4-0-4)* |
| *Sophomore Year*<br><br>*CHEM 223 Intro Org. Chem. I (3-0-3)*<br>*[or CHEM 323 Org. Chem. I (3-0-3)]*<br>*CHEM 233 Org. Chem. Lab I (1-3-2)*<br>*PHYS 115 Intro Phys. I (4-0-4)* | *Sophomore Year*<br><br>*CHEM 224 Intro Org. Chem. II (3-0-3)*<br>*[or CHEM 324 Org. Chem. II (3-0-3)]*<br>*CHEM 234 Org. Chem. Lab II (1-3-2)*<br>*PHYS 116 Intro Phys. II (4-0-4)* |
| *Junior Year*<br><br>*CHEM 301 Intro Phys. Chem. I (3-0-3)*<br>*CHEM 304 Quant. Anal. Chem. (2-6-4)* | *Junior Year*<br><br>*CHEM 302 Intro Phys. Chem. II (3-0-3)*<br>*CHEM 305 Intro Phys. Chem. Lab (1-6-3)** |
| *Senior Year*<br><br>*Electives*<br>*Capstone Project* | *Senior Year*<br><br>*Electives*<br>*Capstone Project* |

**Notes**:

*The required Chemistry course CHEM 305 is an approved SAGES Departmental Seminar

*Required Departmental Courses*

| Course | Credits |
|---|---|
| *CHEM 105 & CHEM 106* | *3 + 3* |
| *CHEM 113 & CHEM 114* | *2 + 2* |
| *CHEM 323 & CHEM 324* | *3 + 3* |
| *CHEM 304* | *4* |
| *CHEM 322* | *3* |
| *CHEM 335 & CHEM 336* | *3 + 3* |
| *CHEM 331 & 332** | *3 + 3* |
| *CHEM 310* | *3* |
| *CHEM 328 or CHEM 329 or BIOC 307* | *3 or 4* |
| *CHEM 397 or CHEM 398* | *3* |
| *CHEM Electives* | *6* |
| *TOTAL* | *53 (54)* |

*Additional Required Courses*

| Course | Credits |
|---|---|
| *MATH 121 & MATH 122* | *4 + 4* |
| *MATH 223 & 224 (or STAT 312)* | *3 + 3* |
| *PHYS 121 & 122 (or PHYS 123 & 124)* | *4 + 3* |
| *Technical Electives* | *6* |
| *TOTAL* | *31* |

*Summary*

| Component | Credits |
|---|---|
| *SAGES (17), CAS GER (18)* | *35*** |
| *Chemistry* | *53 (54)* |
| *Other Required Courses* | *31* |
| *Open Electives* | *to make at least 120* |
| *TOTAL* | *120* |

**Notes**:

*The required Chemistry course CHEM 332 is an approved SAGES Departmental Seminar-no other course is needed.
** Due to overlap in requirements in CHEM 332, this number is reduced by 3 credits. In addition, this total number is further reduced as two courses from your required courses can also be used to fulfill CAS GER breadth requirements in Natural and Mathematical Sciences.

*B.S. in Chemistry, Recommended Sequence for required Science and Math Courses*

B.S. in Chemistry

| Fall Semester<br>Class/Lab/Credit Hours | Spring Semester<br>Class/Lab/Credit Hours |
|---|---|
| *First Year*<br><br>*CHEM 105 Principles of Chem. I (3-0-3)*<br>*CHEM 113 Principles of Chem. Lab (1-3-2)*<br>*MATH 121 Calculus for Sci. & Eng. I (4-0-4)* | *First Year*<br><br>*CHEM 106 Principles of Chem. II (3-0-3)*<br>*CHEM 114 Chem. Frontiers Lab (1-3-2)*<br>*MATH 122 Calculus for Sci. & Eng. II (4-0-4)*<br>*PHYS 121 Gen. Phys. I. (4-0-4)* |
| *Sophomore Year*<br><br>*CHEM 323 Org. Chem. I (3-0-3)*<br>*CHEM 304 Quant. Anal. Chem. (2-6-4)*<br>*MATH 223 Calculus for Sci. & Eng. III (3-0-3)*<br>*PHYS 122 Gen. Phys. II. (4-0-4)* | *Sophomore Year*<br><br>*CHEM 324 Org. Chem. II (3-0-3)*<br>*CHEM 322 Lab. Methods Org. Chem. (1-6-3)*<br>*MATH 224 Elementary Diff. Eq. (3-0-3)*<br>*[or STAT 312 Stats. for Eng. Sci. (3-0-3)]*<br>*PHYS 221 Gen. Phys. III. (3-0-3)* |
| *Junior Year*<br><br>*CHEM 335 Phys. Chem. I (3-0-3)*<br>*CHEM 331 Lab. Methods Inorg. Chem. (1-6-3)*<br>*CHEM 311 Inorg. Chem. (3-0-3)* | *Junior Year*<br><br>*CHEM 336 Phys. Chem. II (3-0-3)*<br>*CHEM 332 Lab. Methods Phys.. Chem. (1-6-3)**<br>*Chemistry or approved elective (3-0-3)* |
| *Senior Year*<br><br>*CHEM 310 Instrum. Anal. Chem. (3-0-3)*<br>*Biochemistry Requirement***<br>*Technical Elective (3-0-3)*<br>*CHEM 398 Chemistry Capstone Project (0-9-3)*<br>*or CHEM 397 UG Research in Chem. (0-9-3)* | *Senior Year*<br><br>*Chemistry or Approved Elective (3-0-3)*<br>*Technical Elective (3-0-3)*<br>*CHEM 398 Chemistry Capstone Project (0-9-3)*<br>*or CHEM 397 UG Research in Chem. (0-9-3)* |

**Notes**:

*The required Chemistry course CHEM 332 is an approved SAGES Departmental Seminar
** May be fulfilled by taking CHEM 328, CHEM 329, or BIOC 307

# Electives for B.S. in Chemistry

The sequence of required Chemistry courses for the BS degree described above represents a "Core Set" of Chemistry courses comprising 47(48) credit hours. In addition to these required chemistry courses, the BS major is required to complete an additional 6 credit hours of **Chemistry Electives** and 6 credit hours of **Technical Electives**.

The **Chemistry Electives** may be any chemistry department course at the 300 level or above which is not part of the "core set", or courses with a strong chemistry content at the 300 level or above from other science departments. Only 3 additional credit hours of CHEM 397 or CHEM 398 may be applied as a Chemistry Elective. Six additional credit hours of CHEM 397 or CHEM 398 may be taken as Technical Electives. (Further additional credit hours of CHEM 397 may be taken as Open Electives).

The **Technical Electives** may be chosen more widely from any of the natural sciences, math, or engineering courses and may include introductory level courses, i.e., 100, 200 level courses, in technical disciples other than chemistry.

# Tracks for B.S. Chemistry Majors

Chemistry is recognized as the "Central Science" and, as such, provides a fundamental background of knowledge that may be applied to a variety of disciplines. The following courses are recommended as good choices of **Chemistry Electives** for students who wish to emphasize coursework in a particular sub-discipline of Chemistry.

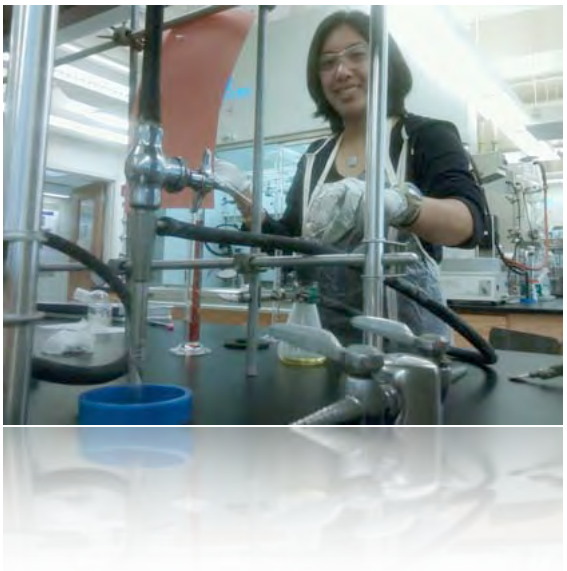
**Physical Chemistry:** CHEM 406, 407, 446, 447
**Organic Chemistry:** CHEM 325, 421, 422
**Inorganic Chemistry:** CHEM 312, 412, 413, 414, 415, 479
**Analytical Chemistry:** CHEM 325, 479
**Biochemistry:** CHEM 328, CHEM 329, BIOC 334

Students who wish to sample a closely related science discipline while completing the requirements for the BS degree are advised to consider the following recommended courses. Several of these courses are suitable **Chemistry Electives** and all of them are appropriate as **Technical Electives**.

**Environmental Chemistry Track**
GEOL 202. Global Environmental Problems (3)*
GEOL 336 Aquatic Chemistry (4)*
GEOL 350 Geochemistry (3)*
GEOL 437 Chemistry of Natural Waters (3)*
BIOL 350 Intro to Ecosystem Analysis and Environmental Science (3)

**Materials Science Track**
EMSE 201. Introduction to Materials Science (3)
EMSE 270. Materials Laboratory I (2)
EMSE 314 Electronic, Magnetic & Optical Properties of Materials (3)

**Polymer Science Track**
EMAC 270 Introduction to Polymer Science (3)
EMAC 276 Polymer Properties and Design (3)
EMAC 303 Structure of Biologic Materials (3)



*These courses are offered every other year


# Minor in Chemistry

A minor in Chemistry is defined as: one year of Freshman Chemistry (including laboratory); two additional three-hour lecture courses; and two additional laboratory or approved courses. The Academic Affairs Office of the department (Clapp 204) should be contacted by interested students. A recommended sequence is:

CHEM 105, 106 Principles of Chem. I, II
and
CHEM 113 Principles of Chem. Lab

CHEM 223, 224 Introductory Organic Chem. I, II
or
CHEM 323, 324 Organic Chem. I, II
and
CHEM 223, 234 Introductory Organic Chem. Lab I, II

Other sequences can be followed after consultation with the Chemistry Department.

# Certification by the American Chemical Society

The American Chemical Society is the major professional society in the United States for practicing chemists. The ACS sponsors major professional meetings and publishes a large number of scientific journals. Through its Committee on Professional Training, the ACS evaluates undergraduate professional education in chemistry throughout the U.S. Students who successfully complete an undergraduate curriculum which meets the ACS guidelines receive certification by the Society. These guidelines are lengthy but basically require 400 clock hours of traditional class work in chemistry courses covering all of the fundamental areas of the discipline, and 500 clock hours of formal laboratory experience in chemistry. Math and physics courses are also specified. Details of the ACS guidelines may be found at their web site: http://www.chemistry.org

**B.S. Chemistry Majors**

Chemistry majors who complete the BS curriculum will be nominated by the Department to receive certification by the ACS.

**B.A. Chemistry Majors**

BA majors who desire to qualify for American Chemical Society certification for their degree must complete the following additional Chemistry courses:

CHEM 311, Inorganic Chemistry (3 credits),
and
CHEM 328, Introductory Biochemistry (3) or BIOC 307, General Biochemistry I (4 credits) or CHEM 329, Chemical Aspects of Living Systems (3 credits)
and Complete 5 credit hours* of CHEM 397, Undergraduate Research or CHEM 398, Undergraduate Research/Senior Capstone Project. The research project must culminate in a written report. Students who carry out chemistry-based research in other departments may petition the Undergraduate Committee to count this research toward ACS accreditation.

** Students who have completed CHEM 114, Frontiers Chemistry Laboratory, need take only 4 credit hours of CHEM 397 or CHEM 398.*

# Transfer Credit for Courses Taken at Other Universities

***(See the General Bulletin for Case Western Reserve University for Rules governing Transfer Credit.)***

Undergraduate Chemistry majors who desire to take Chemistry, Physics or Math courses at other universities or colleges (including Junior year abroad programs) and have these courses fulfill requirements for the Chemistry major curriculum at Case are advised to seek prior approval from the Chemistry Department for these courses. In general, courses for which transfer credit is sought should be nearly equivalent in content and course duration to the Case course which is being substituted.

The following statements will also help you to select appropriate courses at other schools.

1. Only calculus-based Physics courses will be allowed to substitute for Case Physics courses that are required for the BS in chemistry.
2. Only calculus-based Physical Chemistry courses will be allowed to substitute for Case Physical Chemistry courses.


# Summer Research Opportunities at CWRU

In past years, limited opportunities have been available for qualified undergraduate students from Case Western Reserve University and elsewhere to participate in on-going research projects. The appointments usually carry stipends, in which case no academic credit is granted. Interested students should contact faculty members on their own initiative, since many of the summer research arrangements are made informally. Students may also register for CHEM 397 (or CHEM 398) for course credit during the summer months.

In addition, CWRU has created SOURCE (Support for Undergraduate Research and Creative Endeavors) to help coordinate research opportunities and to provide funding for research experiences.
Please see their web site for further information: http://www.case.edu/provost/source/

Students interested in areas that overlap with biological sciences may wish to look at the SPUR website (http://www.case.edu/artsci/biol/hhmi/spur.htm) for other possible funding for summer research in biology, chemistry, and biochemistry.

# Chemistry Co-op Program

The Co-op program in Chemistry offers a rigorous curriculum leading to a Bachelor of Science degree together with an opportunity for a 12- or 15- month industrial internship experience. This program of courses provides a strong background in the basic chemical sciences which is appropriate for either the student who intends to pursue advanced post-graduate studies or the student who enters industrial employment at the B.S. level. Since chemistry is a central science, graduating majors have a wide range of career opportunities in research and development, analytical quality control, technical sales and product development, and scientific writing. Many students elect graduate study leading to M.S. and Ph.D. degrees in chemistry or related chemical sciences. The B.S. degree in chemistry also provides entry into professional training for medicine, dentistry, veterinary science, law and business. The B.S. chemistry curriculum on which this co-op program is based receives full certification by the American Chemical Society, the major professional society in the United States for practicing chemists.

| Year | Fall | Spring | Summer |
|---|---|---|---|
| *1* | *Study* | *Study* | |
| *2* | *Study* | *Study* | |
| *3* | *Study* | *Study* | *Co-op* |
| *4* | *Co-op* | *Co-op* | *Co-op* |
| *5* | *Study* | *Study* | |

The preferred Co-op program in chemistry is shown above. It offers a 15-month internship experience between the junior and senior years of study. This is a highly appropriate time for the internship since most of the required chemistry, math and physics courses are completed at this point. A typical internship in the chemistry program would be spent in an industrial research laboratory and would involve participation in a basic research or product development program. The Cleveland area is a major center for chemical industry including companies with laboratories involved in petroleum research, paint and coatings technology, tire and rubber development, electrochemical research, pharmaceutical and agricultural chemicals. An alternate plan for the Co-op program would place a 12-month internship between the fall and spring semesters of the third year of the chemistry program.


# Undergraduate Bulletin Board

Bulletin boards in the second floor hallway connecting the Millis Science Center with Clapp Hall contain announcements and information of interest to undergraduate chemistry majors. Job opportunities are also posted on these boards. Bulletin boards should be checked regularly. Listings of graduate study opportunities at other universities also may be found on the second floor bulletin boards located in the passageway between Millis and Clapp.


# Awards and Prizes Available to Chemistry Majors

Every Spring the Chemistry Department holds an Awards Luncheon to honor students in Chemistry. Many undergraduates, at all possible points along their CWRU studies, are honored with

**The Ignacio Ocasio Freshman Chemistry Achievement Award**, for achievement in freshman chemistry.

**The Olin Freeman Tower Prize,** for excellence in physical chemistry.

**The Hippolyte Gruener Prize,** for merit in chemistry.

**Charles F. Mabery Prize,** for best undergraduate chemistry thesis.

**The Iota Sigma Pi Frank Hovorka Award**, to a woman chemistry major having the highest average in three semesters' work in chemistry.

**Eli Lilly Award,** to an outstanding sophomore or junior chemistry student.

**Merck Index Award,** to an outstanding chemistry student.

**Hypercube Scholar Award**, HyperChem software prize to an outstanding chemistry student.

**The Charles F. Mabery Prize:** Awarded to the undergraduate or graduate student presenting the best thesis of his/her class on a subject connected with research in the Department of Chemistry. The prize was established in 1928 by Professor Charles F. Mabery, former head of the Department of Chemistry.

**The Carl F. Prutton Prize:** Established by Kent H. Smith, '17, Kelvin Smith, '22 and Vincent K. Smith in honor of Carl F. Prutton '20, for many years as head of the Department of Chemistry and Chemical Engineering and a consultant to the Lubrizol Corporation. Awarded to the senior majoring in Chemistry who achieves the highest grade record in his/her courses in chemistry.

**The W. R. Veazey Prize:** Awarded to a junior achieving the highest academic record in physical chemistry courses. Established by Dr. Carl F. Prutton '20 honoring W. R. Veazey, for 29 years a member of the Case Faculty.

**Mateescu Citizenship Award,** for citizenship

**Chemistry Department Travel Award,** for travel to regional and national chemistry meetings

# Undergraduate Course Descriptions

**CHEM 105. Principles of Chemistry I (3)**
Atomic structure; thermochemistry; periodicity, bonding and molecular structure; intermolecular forces; properties of solids; liquids, gases and solutions.
Prereq: One year of high school chemistry.

**CHEM 106. Principles of Chemistry II** (**3**)
Thermodynamics, chemical equilibrium; acid/base chemistry; oxidation and reduction; kinetics; spectros-copy; introduction to nuclear, organic, inorganic, and polymer chemistry.
Prereq: CHEM 105 or equivalent.

**CHEM 111. Principles of Chemistry for Engineers** (**4)**
A first course in University Chemistry emphasizing chemistry of materials for engineering students. Atomic theory and quantitative relationships; gas laws and kinetic theory; solutions, acid-base properties and pH; thermodynamics and equilibrium; kinetics, catalysis, and mechanisms; molecular structure and bonding.
Prereq: One year of high school chemistry or permission of department.

**CHEM 113. Principles of Chemistry Laboratory** (**2**)
A one semester laboratory based on quantitative chemical measurements. Experiments include analysis, synthesis and characterization, thermochemistry and chemical kinetics. Computer analysis of data is a key part of all experiments.
Coreq: CHEM 105, CHEM 106, CHEM 111, or ENGR 145.

**CHEM 114. Chemistry Frontiers Laboratory (2)**
An introduction to laboratory techniques and computer-based methods for chemical research for the chemistry major. Scientific information databases, structural chemistry, experimental design and data handling, chemical synthesis and characterization.
Prereq: CHEM 105 or CHEM 111, CHEM 113. Coreq: CHEM 106.

**CHEM 223. Introductory Organic Chemistry I (3)**
Introductory course for engineering students and science majors. Develops themes of structure and bonding along with elementary reaction mechanisms. Includes extensive treatment of hydrocarbons, alkyl halides, alcohols, and ethers as well as an introduction to spectroscopy.
Prereq: CHEM 106 or CHEM 111.

**CHEM 224. Introductory Organic Chemistry II (3)**
Continues and extends themes of structure and bonding from CHEM 223 and continues spectroscopy and more complex reaction mechanisms. Includes extensive treatment of aromatic rings, carbonyl compounds, amines, and selected special topics.
Prereq: CHEM 223 or CHEM
323.

**CHEM 233. Introductory Organic Chemistry Laboratory I (2)**
An introductory organic laboratory course emphasizing microscale operations. Synthesis and purification of organic compounds, isolation of natural products, and systematic identification of organic compounds by physical and chemical methods.
Prereq: CHEM 113 and CHEM 106 or equivalent. Coreq: CHEM 223 or CHEM 323.

**CHEM 234. Introductory Organic Chemistry Laboratory II** (**2**)
A continuation of CHEM 233, involving multi-step organic synthesis, peptide synthesis, product purification and analysis using sophisticated analytical techniques such as chromatography and magnetic resonance spectroscopy.
Prereq: CHEM 233.

**CHEM 290. Chemical Laboratory Methods for Engineers (3)**
Techniques of chemical synthesis, analysis, and characterization. Uses students' backgrounds in general and organic chemistry, but requires no background in chemical laboratory operations.
Coreq: CHEM 223 or CHEM 323.

**CHEM 301. Introductory Physical Chemistry I (3)**
First of a two-semester sequence covering principles and applications of physical chemistry, intended for chemistry and chemical engineering majors and other students having primary interests in biochemical, biological or life-science areas. States and properties of matter. Thermodynamics and its application to chemical and biochemical systems. Chemical equilibrium. Electrochemistry.
Prereq: CHEM 106 or equivalent and a year each of physics and calculus, preferably including partial derivatives.

**CHEM 302. Introductory Physical Chemistry II** (**3**)
Continuation of CHEM 301. Chemical kinetics and catalysis. Introductory quantum chemistry. Spectroscopy. Statistical thermodynamics.
Prereq: CHEM 301 or CHEM 335.

**CHEM 304. Quantitative Analytical Chemistry (4)**
A one-semester laboratory course involving quantitative chemical measurements, error analysis and advanced concepts in ionic equilibria. Electrogravimetic and volumetric analysis; separation techniques; metal complexation. Basic chemical instrumentation.
Prereq: CHEM 106, CHEM 113, & CHEM 114 or CHEM 234.

**CHEM 305. Introductory Physical Chemistry Laboratory (3)**
A one-semester laboratory course focusing on the principles and quantitative characterization of chemical and biochemical systems. Experiments include, chemical equilibrium, kinetics, electrochemistry, spectroscopy and the use of computers for the statistical analysis of experimental data. Seminar discussions and disciplinary writing of results.
Prereq: CHEM 304 and CHEM 301 or CHEM 335. Coreq: CHEM 302 or CHEM 336.
Approved SAGES Departmental Seminar

**CHEM 310. Instrumental Analytical Chemistry (3)**
Principles and applications of analytical instrumentation including optical spectroscopy (UV-vis, IR, Raman), photoelectron and ion bombardment spectrometry, NMR and magnetic resonance imaging.
Prereq: CHEM 301 and 302 or CHEM 335 and 336, or equivalent.

**CHEM 311. Inorganic Chemistry I (3)**
Fundamentals of inorganic chemistry. Topics include molecular structure, molecular shape and symmetry, structure of solids, d-metal complexes, oxidation and reduction, and acids and bases.
Prereq: CHEM 301 or CHEM 335 (may be taken concurrently).

**CHEM 312. Inorganic Chemistry II** (**3**)
Continuation of CHEM 311. Fundamentals of inorganic chemistry. Topics include electronic spectra of complexes, structures and properties of solids, organometallic compounds, and descriptive chemistry of representative elements.
Prereq: CHEM 311.

**CHEM 322. Laboratory Methods in Organic Chemistry (3)**
Experimental approach to the synthesis, purification and characterization of organic compounds. Nuclear magnetic resonance (NMR) and infrared (IR) spectroscopies; chromatographic techniques.
Prereq: CHEM 304 or CHEM 223 or CHEM 323. Coreq: CHEM 224 or CHEM 324.

**CHEM 323. Organic Chemistry I (3)**
An enriched course for the sufficiently able and interested student who wishes a deeper and broader appreciation of theory and practice of organic chemistry. Focuses on relationships between molecular structure and chemical reactivity, and stresses the development of sophisticated problem-solving skills in the context of organic reaction mechanisms and multi-step synthesis. Homolytic and heterolytic substitution, elimination, oxidation and reduction reactions; topics in stereochemistry and spectroscopy. Recommended for chemistry, biochemistry, and related majors.
Prereq: CHEM 106 or equivalent and consent of department.

**CHEM 324**. **Organic Chemistry II (3)**
Continuation of CHEM 323. Introduces the chemistry of carbonyl, aromatic and amino functional groups, and develops the concepts of conjugation and resonance, molecular orbital theory and pericyclic reactions.
Prereq: CHEM 223 or CHEM 323 and consent of department,

**CHEM 325. Physical Methods for Determining Organic Structure (3)**
Structure determination of organic compounds using mass spectrometry and modern instrumental techniques such as infrared, ultraviolet, visible, and nuclear magnetic resonance spectroscopy.
Prereq: Two semesters of organic chemistry.

**CHEM 328. Introductory Biochemistry (3)**
A survey of modern biochemistry as viewed from a chemistry perspective. Amino acids and peptides. Protein structure, folding, and dynamics. DNA and RNA. Saccharides, lipids, and biological membranes. Chemical mechanisms of enzyme catalysis. Glycoly-sis, ATP utilization, and oxidative phosphorylation. Metabolism. Expression and transmission of genetic information.
Prereq: CHEM 224 or CHEM 324.

**CHEM 329. Chemical Aspects of Living Systems** (**3**)
A series of special topics in the chemistry of biological processes at the level of chemical structure and molecular mechanisms. Topics will be chosen from the following: Nature of enzymatic rate enhancements. Coenzyme chemistry. Biosynthesis. Enzymatic and nonenzymatic fatty acid metabolism. Bioenergetics: mitochondrial and photosynthetic electron transport and vision. Neurotransmitters and hormone action. Receptors and signal transduction. Factors affecting biological activity and drug design. Xenobiotic metabolism. Carcinogenesis and DNA repair.
Prereq: Two semesters of organic chemistry. One semester of physical chemistry recommended.

**CHEM 331. Laboratory Methods in Inorganic Chemistry** (**3**)
Synthesis, separation techniques, physical properties, and analysis. Advanced techniques of chemical synthesis, leading the student to the preparation of interesting inorganic and organometalhc compounds.
Prercq: CHEM 322.

**CHEM 332. Laboratory Methods in Physical Chemistry** (**3**)
Modern techniques of physicochemical measurement, including, kinetics, spectroscopy, and electrochemistry and the use of statistical methods for the analysis of experimental data. Seminar discussions and disciplinary writing of results.
Coreq: CHEM 336.
Approved SAGES Departmental Seminar.

**CHEM 335. Physical Chemistry I (3)**
First of a two-semester sequence of physical chemistry for chemistry majors and others with career goals in the physical sciences or engineering. States of matter. Kinetic theory of gases. Transport phenomena. Chemical thermodynamics and its application to chemical systems. Equilibrium. Ionic solutions and electrochemistry. Introduction to chemical kinetics.
Prereq: CHEM 106 or equivalent plus a year each of physics and calculus, including partial derivatives.

**CHEM 336. Physical Chemistry II (3)**
Continuation of CHEM 335. Reaction kinetics and catalysis. Reaction dynamics. Chemical quantum mechanics. Statistical mechanics and thermodynamics. Spectroscopy (including optical spectroscopies, magnetic resonance, and mass spectrometry).
Prereq: CHEM 335.

**CHEM 337. Quantum Mechanics I (3)**
Introduction to quantization, measurement and the Schrödinger equation; angular momentum and states of molecules. Perturbation theory, spectroscopy and chemical bonding. Variational theory and calculations of molecular properties.
Prereq: CHEM 336.

**CHEM 395. Chemistry Colloquium Series (1)**
Course content provided by Thursday chemistry department colloquia (or Frontiers in Chemistry lectures). Discussion sessions review previous lectures and lay foundation for forthcoming lectures.

**CHEM 397. Undergraduate Research (1-6)** Independent project within a research group in the chemistry department or, by approval, within a research group in another Case department. Arrangements should be made by consultation with the faculty member selected. Open to all chemistry majors and other qualified students. Satisfies the research requirement for Honors in Chemistry.* A written report is required each semester.
Prereq: Consent of department.

**CHEM 398. Undergraduate Research/Senior Capstone Project (3-6)** Independent project within a research group in the chemistry department or, by approval, within a research group in another Case department. Arrangements should be made by consultation with the faculty member selected and the Senior Capstone Committee of the chemistry department. Open to all chemistry majors and other qualified students. Satisfies the research requirement for Honors in Chemistry.* A written report and public oral presentation is required. (Approved Sages Capstone)
Prereq: Consent of department.

[**when in total of 6 credits, or used in combination with CHEM 397/8 for a total of 6 credits*]

# Selected Graduate Course Descriptions

***(Suggested as advanced electives)***

**CHEM 406. Chemical Kinetics (3)**
Theory and characterization of chemical rate processes. Two semesters of undergraduate physical chemistry required.

**CHEM 407. Chemical Thermodynamics (3)**
Thermodynamics and statistical thermodynamics and their application to chemical problems. Two semesters of undergraduate physical chemistry required.

**CHEM 408. Advanced Physical Chemistry (3)**
Topics in physical chemistry, intended for entering graduate students, giving background tools appropriate for graduate research in areas of chemistry other than physical chemistry. Illustrations from the contemporary chemical research literature will be emphasized. Thermodynamics and statistical mechanics, quantum chemistry and computation, spectroscopy, and chemical kinetics and dynamics.

**CHEM 410. Instrumental Analytical Chemistry (3)**
Principles and applications of analytical instrumentation including optical spectroscopy, photoelectron and ion bombardment spectrometry, mass spectrometry, NMR and magnetic resonance imaging. Two semesters of undergraduate physical chemistry required.

**CHEM 412. Advanced Inorganic Chemistry I (3)**
Chemistry of inorganic systems. Spectroscopy, magnetism, and stereochemistry of transition metal compounds. One semester of undergraduate inorganic and two semesters of physical chemistry required.

**CHEM 413. Advanced Inorganic Chemistry II (3)**
Chemistry of inorganic compounds; mechanisms of reactions. Prerequisite course or its equivalent required. Prerequisite: CHEM 412

**CHEM 414. Organometallic Reactions and Structures (3)**
Bonding and structure in organometallic chemistry and the relevance of organometallic species to chemical catalysis. One semester of undergraduate inorganic chemistry required.

**CHEM 415. Chemical Applications of Group Theory (3)**
Experimental and semi-empirical treatments of structure and bonding in chemical systems based on a presentation of relationships and the theory of point and space groups. Prerequisite course or its equivalent required. Prerequisite: CHEM 412

**CHEM 421. Advanced Organic Chemistry I (3)**
Elementary general molecular orbital theory. Stereoisomerism. Reaction mechanisms. Pericyclic reactions and orbital symmetry conservation. Organic photochemistry. Free radical, radical ion, carbene, nitrene, aryne intermediates and their reactions. Two semesters of undergraduate organic chemistry required.

**CHEM 422. Advanced Organic Chemistry II (3)**
Carbocations and carbanions. Nucleophilic and electrophilic aliphatic substitutions. Heterolytic addition and elimination reactions. Electrophilic, nucleophilic, and free radical aromatic substitutions. Carbonyl reactions. Oxidations, reductions, rearrangements. Two semesters of undergraduate organic chemistry required.

**CHEM 446. Quantum Mechanics I (3)**
Introduction of quantization, measurement and the Schrödinger equation; angular momentum and states of molecules. Perturbation theory, spectroscopy and chemical bonding. Variational theory and calculations of molecular properties. Two semesters of undergraduate physical chemistry required.

**CHEM 447. Quantum Mechanics II (3)**
(Continuation of CHEM 446.) Abinitio and semi-empirical methods, configuration interaction, time dependent phenomena, and principles of group theory. Prerequisite: CHEM 446

**CHEM 479. X-ray Crystallography (3)**
Scattering of x-rays by crystalline and semi-crystalline solids, including polymers. Techniques of structure analysis. Prereq: Two years of chemistry.

# Undergraduate Research

Undergraduate chemistry majors are encouraged to participate in **CHEM 397, Undergraduate Research** or **CHEM 398, Undergraduate Research/Senior Capstone Project**. Students should consult with faculty members in the department and select one under whose guidance the student undertakes a specific research project. This gives students the opportunity to join a research group and to work with faculty, graduate students, and research associates. Many such research projects have resulted in papers published in scientific journals and coauthored by undergraduate students. Descriptions of current research projects of the Chemistry faculty may be viewed at: http://www.cwru.edu/artsci/chem/ by clicking on Faculty and selecting an individual faculty page.

The rules governing this program are as follows:

1. CHEM 397 and CHEM 398 are normally taken by a student under the supervision of a Chemistry faculty member (including those with a joint appointment in Chemistry). Students who want to carry out CHEM 397 or CHEM 398 research with a faculty mentor must submit a petition to the Undergraduate Committee or Capstone Committee for approval of the proposed project. The proposed project must be primarily chemically-based in order to be approved.
2. Registration for CHEM 397 or CHEM 398 also requires a permit (available in Clapp Hall 212C), signed by the research mentor, specifying the name of the research mentor and the number of credit hours agreed upon.
3. At the end of each semester that CHEM 397 or CHEM 398 is carried out, the student must submit to the research adviser a comprehensive report of the work accomplished. A copy of the report must also be submitted to the Chair of the Undergraduate Committee or Capstone Committee. No grade for CHEM 397 will be issued without the comprehensive report. CHEM 398 carries the extra requirement of a public oral presentation(s) of the research accomplished.
4. A maximum of 3 credit hours of CHEM 397 or 398 may be taken as Chemistry Electives. A maximum of 6 credit hours of CHEM 397 or 398 may be taken as Technical Electives. Additional credit hours of CHEM 397 may be taken as Open Electives.

# Undergraduate Honors Program in Chemistry

Chemistry majors who have excellent academic records are invited at the end of their junior year to participate in the Honors Chemistry Program. To graduate with "Honors in Chemistry" a student must satisfy the following requirements:

**I. Academic Excellence:** Academic excellence must be demonstrated in both chemistry and overall undergraduate course work. This is measured by a combined grade point average of 3.5 in Chemistry, Physics, and Mathematics and an overall grade point average of 3.2.

**II. Undergraduate Research:** A minimum of 6 semester hours of laboratory research involving chemistry must be completed. The research requirements can be satisfied by:

**A.** Research conducted in the Chemistry Department as CHEM 397 or CHEM 398.

**B.** Research done under another course number. Such research must be approved by the Undergraduate Committee of the Chemistry Department with respect to its chemical content. Conditional approval should be sought prior to initiation of the work.

**III. Approval of a Senior Thesis:** A thesis on the completed research in CHEM 397 or CHEM 398 must be approved. All theses will be submitted to the Chemistry Undergraduate Committee along with a recommendation letter from the thesis adviser. The Chemistry Undergraduate Committee will judge each thesis with respect to the level of research, the quality of the manuscript and the chemical content. Special notice should be taken that research done outside of the Chemistry Department will not be judged appropriate for Honors in Chemistry unless its subject matter is primarily chemical. The deadline for submitting a thesis is the last day of classes.

# Special Events of Note for Chemistry Majors

In approximate order as they occur during the year, here are some events in which chemistry majors can participate.

**Chemistry Department Fall Picnic** During the Friday before classes start, the department hosts a picnic for graduate students, undergraduate students, faculty and their families. This is a marvelous opportunity to speak to faculty in a relaxed atmosphere and to enjoy some food.


**Meeting in Miniature** The Cleveland Section of the American Chemical Society holds a 1/2 day long meeting where undergraduates from CWRU and surrounding colleges and universities can present their research to other students and faculty. Undergraduates from CWRU traditionally do well in the competition for awards that are given to outstanding speakers.

**Chemistry Holiday Party** In mid-December the Chemistry Department hosts a Holiday party filled with great food and cheer. Come see the merriment and fun antics when students, faculty, and staff perform skits.

**Research Showcase** CWRU holds a special day long event where graduate and undergraduate researchers can present research posters. See: http://ora.ra.cwru.edu/showcase/ for more details.

**Chemistry Poster Party** Graduate and undergraduate students can present their own research, as well as learn about what other exciting research in going on in the department. This event is held in the Hovorka Atrium.

**Chemistry Awards Luncheon** Right after classes end for Spring semester, the Chemistry Department holds an awards banquet. Graduate and undergraduate awards are presented, as well as a special talk by a chemistry Outstanding Alumnus is given.

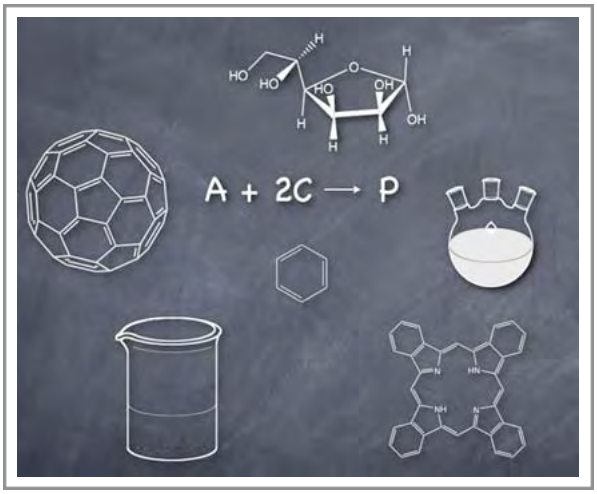
# Alpha Chi Sigma (AXΣ)


Alpha Chi Sigma is a co-ed professional fraternity in chemistry. Membership is open to those studying chemistry, biochemistry, or chemical engineering; as well as related subjects such as molecular biology, ceramic engineering, nutritional science, and many others. Its membership includes undergraduates, graduate students, and professors. The web site for the Gamma chapter at CWRU can be found at: http://www.case.edu/orgs/alphachi/ . While many chemistry majors chose AXΣ to increase their social activities, AXΣ members provide many valuable services to the CWRU and local communities.

# Outstanding UG Chemistry Alumni

Our chemistry graduates go onto a vast range of activities after receiving their B.A. or B.S. degrees from CWRU. At the annual Chemistry Awards luncheon we acknowledge the distinguished careers of our graduates with an award, and the opportunity for the recipient to deliver an awards lecture. Some of these former undergraduates are listed below to demonstrate the breadth of careers and the undeniable success of our alumni.

| Alum (year of award) | Recent Position(s) & Accolades |
|---|---|
| Gregory Kubas (2006) | Los Alamos National Lab |
| Peter B. Armentrout (2004) | Professor of Chemistry & Department Chair at University of Utah |
| Jack Simons (2003) | Professor of Chemistry at University of Utah |
| Arnold L. Rheingold (2002) | Professor of Chemistry at University of California San Diego |
| Sidney M. Wolfe (1999) | Director of Public Citizen's Health Research Group |
| John Law (1997) | Regents Professor and Director of Center for Insect Science at University of Arizona |
| Steve Wolinsky (1996) | Doctor of Medicine, AIDS Specialist at Northwestern University |
| John Kozak (1994) | former provost at Iowa State University<br>now University Professor at DePaul University |
| Antony E. Champ (1992) | former CEO of Fiber Industries<br>now owns White Hall Vineyards and is trustee for CWRU |
| Paul C. Lauterbur (1990) | Professor of Chemistry, Biochemistry, & Computational Biology and Bioengineering<br>Distinguished University Professor of Medical Information Sciences<br>2003 Nobel Prize in Physiology and Medicine |




# Teacher Licensure

B.A. Chemistry majors can participate in the Case Western Reserve University/John Carroll University Collaborative Program that prepares students for state licensure. A degree in this program is awarded by Case Western Reserve University and licensure is recommended through John Carroll University.

In order to receive a teaching license, the Ohio Department of Education also requires that licensure candidates achieve passing scores on the PLT (Principles of Learning and Teaching) and Content Area subsets of the Praxis II Examination. In addition, applicants must pass a criminal background check by the Ohio Bureau of Criminal Identification.

**Overview of Credit hours:**

Subtotal Required Education Licensure Credit Hours Taken at Case: 12 CWRU Credit Hours

Subtotal Required Education Licensure Credit Hours Taken at John Carroll University: 23 EDJC Credit Hours

Required Credit Hours for Case/JCU Adolescence to Young Adult Teacher Licensure: 35 Total Credit Hours

For more details see: http://www.case.edu/artsci/teachlic/index.html

# Frequently Asked Questions

*Q: Can I use the same exact report for CHEM 398 or CHEM 397 for the Honors in Chemistry Thesis?*

A: The Honors in Chemistry program requires 6 hours of UG research as either CHEM 398 or CHEM 397, thus your thesis must cover at least this amount of effort. It is possible that for some students who take 6 (or more) credits of either of these courses in a single semester that the reports may be identical.

*Q: If I am a double (or more) major, do I have to do 2 (or more) capstone courses?*

A: No. The SAGES program only requires a single capstone experience.

*Q: Can I get into a Chemistry graduate (PhD) program even though I will get a B.A. degree, as opposed to B.S. degree?*

A: Absolutely! There is a strong demand for students interested in PhD studies across the US.

*Q: Where can I get the proper forms to [insert your needs here]?*

A: Chemistry forms can be obtained from the Chemistry Academic Affairs office in Clapp 204. Other forms are available in Undergraduate Studies and can be downloaded at: http://www.case.edu/provost/ugstudies/forms.htm

*Q: Who can I see if I need more help and want to talk to someone?*

A: You should see either your assigned Chemistry advisor, or Professor John Stuehr in Clapp 207, or the Chair of the Undergraduate Committee.

*Q: How do I get my PIN number?*

A: Please make an appointment with your Chemistry advisor to receive you PIN number and for guidance.

# Faculty of the Department

| Faculty | PhD | Title |
|---|---|---|
| **Alfred B. Anderson** | Johns Hopkins University, 1970 | Professor |
| **Mary D. Barkley** | University of California-San Diego, 1969 | Professor |
| **Clemens Burda** | University of Basel, 1997 | Associate Professor |
| **James Burgess** | Virginia Commonwealth University, 1997 | Associate Professor |
| **Carlos Enrique Crespo Hernández** | University of Puerto Rico, 2002 | Assistant Professor |
| **Robert C. Dunbar** | Stanford University, 1970 | Professor |
| **Thomas Gray** | Harvard University, 2002 | Assistant Professor |
| **Malcolm E. Kenney** | Cornell University, 1954 | Hurlbut Professor |
| **Michael J. Kenney** | Iowa State University, 1990 | Teagle Professorial Fellow |
| **Irene Lee** | The Pennsylvania State University, 1995 | Associate Professor |
| **Anthony J. Pearson** | University of Aston (England), 1974 | Rudolph and Susan Rense Professor |
| **John D. Protasiewicz** | Cornell University, 1990 | Professor |
| **Robert G. Salomon** | University of Wisconsin-Madison, 1971 | Professor |
| **Lawrence M. Sayre** | University of California at Berkeley, 1977 | Hovorka Professor & Chair of the Department of Chemistry |
| **Daniel A. Scherson** | University of California, Davis, 1979 | Charles F. Mabery Professor |
| **Regan L. Silvestri** | Case Western Reserve University, 1994 | Lecturer |
| **Rekha R. Srinivasan** | Case Western Reserve University, 2003 | Lecturer |
| **John E. Stuehr** | Case Western Reserve University, 1961 | Professor |
| **Gregory P. Tochtrop** | Washington University School of Medicine, 2002 | Assistant Professor |
| **Michael G. Zagorski** | Case Western Reserve University, 1983 | Professor |

# Associate Faculty

| Faculty | Department (School) | Title |
|---|---|---|
| **Vernon Anderson** | Biochemistry (Medicine) | Professor |
| **Paul Carey** | Biochemistry (Medicine) | Professor |
| **John Crabb** | Ophthamology (Cleveland Clinic) | PhD |
| **John J. Mieyal** | Pharmacology (Medicine) | Professor |
| **Stuart J. Rowan** | Macromolecular Science (Engineering) | Associate Professor |
| **Witold Surewicz** | Physiology (Medicine) | Professor |
| **Christoph Weder** | Macromolecular Science (Engineering) | Professor |
| **Yanming Wang** | Radiology (Medicine) | Associate Professor |

The **Chemistry Undergraduate Committee** consists of the following members:

John Protasiewicz (Undergraduate Committee Chairman)

James Burgess (faculty)

Anthony Pearson (faculty)

Rekha Srinivasan (faculty)

Lawrence Sayre (Department Chairman), *ex officio*

John Stuehr (Associate Chairman), *ex officio*

Kenneth Hecht (undergraduate student representative)

Mark Lipke (undergraduate student representative)

and is greatly supported by **Zedeara Pratt** who staffs the Academic Affairs Office in Clapp 204