INFORMATION FOR
UNDERGRADUATE CHEMISTRY MAJORS
CASE WESTERN RESERVE UNIVERSITY

2005-2006

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, 2004 and thereafter. Students who entered the University prior to Fall, 2004 should obtain a list of the old course requirements from the Academic Affairs Office, Clapp 204.

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.

The Chemistry Undergraduate Committee consists of the following members:

Anthony Pearson	(Undergraduate Committee Chairman)
Mary Barkley	(faculty)
John Protasiewicz	(faculty)
Lawrence Sayre	(Department Chairman), *ex officio*
John Stuehr	(Associate Chairman), *ex officio*
Richard Schenkelberg	(undergraduate student representative)
Thomas Teets	(undergraduate student representative)

The Chemistry Office of Student Affairs is located in 204 Clapp Hall.
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Revised 03/2006

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FACULTY OF THE DEPARTMENT

Alfred B. Anderson, Ph.D. Johns Hopkins University, 1970; Professor of Theoretical Chemistry
Mary D. Barkley, Ph.D. University of California-San Diego, 1969, Professor of Biophysical Chemistry
Clemens Burda, Ph.D. University of Basel, 1997; Assistant Professor of Physical Chemistry
James Burgess, Ph.D. Virginia Commonwealth University, 1997; Assistant Professor of Electrochemistry
Robert C. Dunbar, Ph.D. Stanford, 1970; Professor of Physical Chemistry
Philip Garner, Ph.D. Pittsburgh, 1981; Professor of Organic Chemistry
Thomas Gray, Ph.D. Harvard, 2002, Assistant Professor of Inorganic Chemistry
Malcolm E. Kenney, Ph.D. Cornell University, 1954; Hurlbut Professor- Inorganic Chemistry
Irene Lee, Ph.D. The Pennsylvania State University, 1995, Associate Professor of Bio-Organic Chemistry
Anthony J. Pearson, Ph.D. University of Aston (England), 1974; Rudolph and Susan Rense Professor of Organic Chemistry
John D. Protasiewicz, Ph.D. Cornell , 1990; Professor of Inorganic Chemistry
Robert G. Salomon, Ph.D. University of Wisconsin-Madison, 1971; Professor of Organic Chemistry
Lawrence M. Sayre, Ph.D. University of California at Berkeley, 1977; Hovorka Professor and Department Chair of the Department of Chemistry- Organic Chemistry
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John E. Stuehr, Ph.D. Case Western Reserve University, 1961; Professor of Physical Chemistry and Associate Chair of the Department of Chemistry
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Vernon Anderson, Ph.D. University of Wisconsin, 1981, Associate Professor of Biochemistry
Paul Carey, D. Phil. University of Sussex, England, Professor of Biochemistry
John Crabb, Ph.D. Department of Ophthalmology, Cleveland Clinic
John J. Mieyal, Ph.D. Case Western Reserve University, 1969; Professor of Pharmacology and Chemistry
Witold Surewicz, Ph.D., University of Lodz, Poland, 1981**,** Professor of Physiology and Biophysics

THE DEPARTMENT OF CHEMISTRY

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. 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.

CHEMISTRY ADVISERS

When a student has declared a chemistry major through his or her respective dean's office, he or she is assigned a chemistry adviser by the Chemistry Department This faculty member remains the student's adviser until graduation, 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.

UNDERGRADUATE 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 curriculum appropriate for a student who needs a strong background in chemistry in order to enter medical school or some other field related to chemistry.

Note the recent change in the Bachelor of Arts in Chemistry Program described on the following pages. The title of the course CHEM 304 has been changed to QUANTITATIVE ANALYTICAL CHEMISTRY to better describe the course content. The number of credit hours for the course has increased from 3 to 4.

The **Bachelor of Science in Chemistry** provides a more intensive coverage of the field 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 or for direct entry into the job market at the baccalaureate level. The Bachelor of Science in Chemistry Program underwent extensive revision in 2004 as reflected in the program summary on the following pages. *This revised BS in Chemistry Program is effective for the class entering Case in Fall 2004 and thereafter.*

For current BS chemistry majors who entered their junior or senior years in the Fall 2005, the following changes in the program apply.

1. ENGR 131 is no longer a required course for the BS in Chemistry. If you have already taken this course it may be applied as a Technical Elective.
2. Chemistry majors who entered the university prior to Fall, 2004 must complete a minimum of 2 credit hours of CHEM 397 to make up for the deficiency of laboratory hours* in the curriculum created by the removal of CHEM 330, Computers in Chemistry Laboratory. If CHEM 397 is taken solely as a replacement for CHEM 330, it cannot also be counted as a Chemistry or Technical Elective.
*With the removal of CHEM 330 from the curriculum, BS chemistry majors must make up **a)** the 2 credit hours to satisfy the number of credit hours for graduation and, **b)** the number of *clock hours* of laboratory experience to satisfy the requirements for American Chemical Society certification of the degree. Therefore, if you take CHEM 397 as a Chemistry Elective, you have satisfied the "clock hours of laboratory requirement" and may then satisfy the "2 credit hour requirement" with any additional chemistry elective, either lecture or lab.

Bachelor of Arts in Chemistry

COMPLETE COURSE REQUIREMENTS

<u>CAS Core Requirements</u> (Students enrolled in the SAGES Program should consult the SAGES literature for the required number of credit hours. Total credit hours required for the B.A. degree is 120.)

Course Work Area	Credits
1. SAGES First Seminar (or English 150 for non-SAGES students)	3
2. Natural Science and Mathematics Quantitative Reasoning Natural Science Science and Society	(12 hrs total) 3 to 9 3 to 9 6 to 3
3. Arts and Humanities The Arts History, Philosophy, and Religion Literature and Language	(12 hrs total) 3 to 6 3 to 6 3 to 6
4. Social Sciences Social Institutions Human Behavior and Development	(9 hrs total) 3 to 6 3 to 6
5. Global and Cultural Diversity	3
Total	**39**

<u>Required Chemistry Courses</u>

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)**

Non-Chemistry Requirements

Course	Credits
MATH 125 or 121	4
MATH 126 or 122	4
PHYS 115	4
PHYS 116	4
PHED 101	0
PHED 102	0
Total	**16**

Summary

Component	Credits
CAS Core	39
Chemistry	31(32)
Other Math and Science	16
Minus Math and Science in Core	-12
Open Electives	46(45)
Total	**120**

Table 1. BACHELOR OF ARTS IN CHEMISTRY DEGREE
(Recommended sequence for the required Science and Math Courses)

Fall Semester	Class/Lab/Credit Hours	Spring Semester	Class/Lab/Credit Hours
Freshman		**Freshman**	
CHEM 105, Principles of Chemistry I	(3)	CHEM 106, Principles of Chemistry II	(3)
CHEM 113, Principles of Chemistry Laboratory	(2)	MATH 126, Mathematics II	(4)
MATH 125, Mathematics I	(4)		
Sophomore		**Sophomore**	
CHEM 223, Introductory Organic Chemistry I	(3)	CHEM 224, Introductory Organic Chemistry II	(3)
or CHEM 323, Organic Chemistry I	(3)	or CHEM 324, Organic Chemistry II	(3)
CHEM 233, Organic Chemistry Laboratory I	(2)	CHEM 234, Organic Chemistry Laboratory II	(2)
PHYS 115, Introductory Physics I	(4)	PHYS 116, Introductory Physics II	(4)
Junior		**Junior**	
CHEM 301, Introductory Physical Chemistry I	(3)	CHEM 302, Introductory Physical Chemistry II	(3)
CHEM 304, Quantitative Analytical Chemistry	(4)	CHEM 305, Introductory Physical Chemistry Lab	(3)
Senior		**Senior**	
Electives		Electives	

Bachelor of Science in Chemistry

COMPLETE COURSE REQUIREMENTS

<u>CAS Core Requirements</u> (Students enrolled in the SAGES Program should consult the SAGES literature for the required number of credit hours. Total credit hours for the B.S. degree is 121(122).)

Course Work Area	Credits
1. SAGES First Seminar (or English 150 for non-SAGES students)	3
2. Natural Science and Mathematics Quantitative Reasoning Natural Science Science and Society	(12 hrs total) 3 to 9 3 to 9 6 to 3
3. Arts and Humanities The Arts History, Philosophy, and Religion Literature and Language	(12 hrs total) 3 to 6 3 to 6 3 to 6
4. Social Sciences Social Institutions Human Behavior and Development	(9 hrs total) 3 to 6 3 to 6
5. Global and Cultural Diversity	3
Total	**39**

Required Chemistry Courses

Course	Credits
CHEM 105	3
CHEM 106	3
CHEM 113	2
CHEM 114	2
CHEM 323	3
CHEM 324	3
CHEM 304	4
CHEM 322	3
CHEM 335	3
CHEM 336	3
CHEM 331	3
CHEM 332	3
CHEM 310	3
CHEM 311	3
CHEM 328, CHEM 329 or BIOC 307 (4)	3 (4)
CHEM 397 or CHEM 398	3
CHEM ELECTIVES	6
Total	**53 (54)**

Non-Chemistry Requirements

Course	Credits
MATH 121	4
MATH 122	4
MATH 223	3
MATH 224 or STAT 312	3
PHYS 121 or 123	4
PHYS 122 or 124	4
PHYS 221 or 223	3
PHED 101	0
PHED 102	0
TECHNICAL ELECTIVES	6
Total	**31**

Summary

Component	Credits
CAS Core	39
Chemistry	53 (54)
Other Requirements	31
Minus Math and Science in Core	-12
Open Electives	9
Total	**120 (121*)**

Table 2. BACHELOR OF SCIENCE IN CHEMISTRY DEGREE
(Recommended sequence for required Science and Math Courses)

Fall Semester	Class/Lab/Credit Hours	Spring Semester	Class/Lab/Credit Hours
Freshman		**Freshman**	
CHEM 105, Principles of Chemistry I	(3-0-3)	CHEM 106, Principles of Chemistry II	(3-0-3)
CHEM 113, Principles of Chemistry Laboratory	(1-3-2)	CHEM 114, Chemistry Frontiers Laboratory	(1-3-2)
MATH 121, Calculus for Science and Engineering I	(4-0-4)	MATH 122, Calculus for Science and Engineering II	(4-0-4)
		PHYS 121, General Physics I. Mechanics.	(4-0-4)[a]
Sophomore		**Sophomore**	
CHEM 323, Organic Chemistry I	(3-0-3)	CHEM 324, Organic Chemistry II	(3-0-3)
CHEM 304, Quantitative Analytical Chemistry	(2-6-4)	CHEM 322, Laboratory Methods in Organic Chemistry	(1-6-3)
MATH 223, Calculus for Science & Engineering III	(3-0-3)	MATH 224, Elementary Differential Equations (3-0-3) or STAT 312, Basic Statistics for Engineering and Science	(3-0-3)
PHYS 122, General Physics II. Electricity & Magnetism.	(4-0-4)	PHYS 221, General Physics III. Modern.	(3-0-3)
Junior		**Junior**	
CHEM 335, Physical Chemistry I	(3-0-3)	CHEM 336, Physical Chemistry II	(3-0-3)
CHEM 331, Laboratory Methods in Inorganic Chemistry	(1-6-3)	CHEM 332, Laboratory Methods in Physical Chemistry	(1-6-3)
CHEM 311, Inorganic Chemistry I	(3-0-3)	Chemistry or approved elective	(3-0-3)
Senior		**Senior**	
CHEM 310, Instrumental Analytical Chemistry	(3-0-3)	Chemistry or approved elective	(3-0-3)
Biochemistry Requirement[b]	(3-0-3) or (4-0-4)	Technical elective	(3-0-3)
CHEM 397 Undergraduate Research	(0-9-3) or		
CHEM 398 Undergraduate Research/Senior Capstone Project	(3-6)		
Technical elective	(3-0-3)		

[a]Selected students may be invited to take PHYS 123, 124, 223 (Honors).

[b]May be fulfilled by CHEM 328, CHEM 329 or BIOC 307

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 selected courses with a strong chemistry content at the 300 level or above from other science departments. Only 3 additional credit hours of CHEM 397 may be applied as a Chemistry Elective. Six additional credit hours of CHEM 397 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.

The Chemistry Department offers CHEM 398 as the Capstone Elective.

Tracks for BS 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
Analytical Chemistry: CHEM 325
Biochemistry: CHEM 329, BIOC 308, 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 352 Environmental Geochemistry (3)
BIOL 350 Introduction 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 and 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)

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 Undergraduate Office of the department (Clapp 204) should be contacted by interested students. A recommended sequence would include:

CHEM 105, 106	Principles of Chemistry I, II
and	
CHEM 113	Principles of Chemistry Laboratory
CHEM 223, 224	Introductory Organic Chemistry I, II
or	

CHEM 323, 324	Organic Chemistry I, II
and	
CHEM 223, 234	Introductory Organic Chemistry , Laboratory I, II

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

CERTIFICATION BY THE AMERICAN CHEMICAL SOCIETY

The American Chemical Society, with its more than 160,000 members, 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 the following Web site:
http://www.chemistry.org/portal/a/c/s/1/acsdisplay.html?DOC=education\cpt\guidelines.html

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.*

Certification by the ACS is viewed favorably for admission to graduate or professional programs. Certified graduates are eligible to become Members of the Society after graduation; other chemistry graduates may become Associate Members after graduation and Members after three years of professional experience in chemistry or chemical engineering.

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 help you to select appropriate courses at other schools.

1. Typically, approval will not be given to take Chemistry, Physics or Math courses at two-year or community colleges to substitute for Case courses.
2. Only calculus-based Physics courses will be allowed to substitute for Case Physics courses that are required for the BS in chemistry.
3. Only calculus-based Physical Chemistry courses will be allowed to substitute for Case Physical Chemistry courses.

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, pcptide 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 in the principles and quantitative characterization of chemical and biomedi-cal systems. Experiments such as phase equilibria, calorimetry, chemical equilibrium, kinetics, electrochemistry, spectroscopy and the use of computers to analyze data. Prereq: CHEM 304 and CHEM 301 or CHEM 335. Coreq: CHEM 302 or CHEM 336.

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 physical measurement, including thermochemistry, kinetics, spectroscopy, and electrochemistry. Prereq: CHEM 331- Coreq: CHEM 336.

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.

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

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 in another department must designate a Chemistry faculty member to act as adviser and submit a petition to the Undergraduate 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 requires a permit (available in Clapp Hall 212C), signed by the Chemistry Department faculty adviser, 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. No grade for CHEM 397 will be issued without the comprehensive report. CHEM 398 carries the extra requirement of a public oral presentation of the research accomplished.

4. A maximum of 3 credit hours of CHEM 397 may be taken as Chemistry Electives. A maximum of 6 credit hours of CHEM 397 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.

AWARDS AND PRIZES AVAILABLE TO CHEMISTRY MAJORS

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

SUMMER RESEARCH OPPORTUNITIES AT CASE

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.

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.

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.

The preferred Co-op program in chemistry is shown. 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 (as shown in the following chart).

SEMESTER

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	