Chemistry

Departmental Counselor: Ka Yee Lee, SCL 007, 702-7068, kayeelee@uchicago.edu
Associate Director of Undergraduate Studies in Chemistry: Vera Dragisich, GHJ 222, 702-3071, v-dragisich@uchicago.edu

Web: chemistry.uchicago.edu

Program of Study

Chemistry is concerned with the preparation, composition, and structure of matter and with the equilibrium and kinetic laws that govern its transformations. The B.A. and B.S. degrees with concentration in chemistry are designed to provide a broad foundation in the three principal branches of that science: inorganic, organic, and physical chemistry. Analytical chemistry, often regarded as an independent branch, is incorporated into the program. Both curricula discuss experimental and theoretical work and emphasize their interdependence. Both degree programs prepare the student for a career in chemistry. However, the B.S. degree offers a more intensive program of study. The B.A. degree also offers thorough study in the field of chemistry, but it provides a wide opportunity for elective freedom and for the pursuit of interdisciplinary interests in areas such as biochemistry, biophysics, chemical physics, geochemistry, premedicine, and education.

Program Requirements

Program Requirements: B.A. The principal distinction between the B.A. and B.S. programs is the number of chemistry courses required. A minimum of eight courses in chemistry beyond the general education requirement (which should be taken in the first year) is required for the B.A. degree.

Program Requirements: B.S. A minimum of twelve courses in chemistry beyond the general education requirement (which should be taken in the first year) is required for the B.S. degree.

Summary of Requirements

General Education		CHEM 11101-11201 or 11102-11202 or 12100-12200† MATH 13100-13200 or higher†
Concentration	1	CHEM 11301 or 11302 or 12300†
	1	MATH 13300 or higher†, or MATH 20200, or STAT 24000
	2	MATH 20000-20100
	3	PHYS 13100-13200-13300 or higher†

plus the following requirements:

	B.A.		B.S.
1	CHEM 20100	2	CHEM 20100-20200
3	CHEM 22000-22100-22200	4	CHEM 22000-22100-22200-22300
2	CHEM 26100-26200	3	CHEM 26100-26200-26300
1	CHEM 26700	1	CHEM 26700
14		1	CHEM 22700 or 26800
		18	

† *Credit may be granted by examination.*

NOTE: Students may not substitute Analysis in R^n (MATH 20300-20400-20500) or other 20000-level courses in mathematics for Mathematical Methods for Physical Sciences (MATH 20000-20100) without also passing an equivalency exam on the material in MATH 20000-20100 that is not covered in these courses. Students should meet with the departmental counselor to obtain prior approval for such substitutions. MATH 20200 and/or STAT 24000 are strongly recommended for chemistry concentrators.

Advanced Placement. Students who earned a score of 5 on the AP test in chemistry are given credit for General Chemistry I, II, III. Many such students elect to take Honors General Chemistry (CHEM 12100-12200-12300).

Honors Chemistry Placement Test. Other students who have successfully completed a rigorous chemistry course in high school may enroll in Honors General Chemistry (CHEM 12100-12200-12300) with adequate performance on the Honors Chemistry Placement Test that is offered to entering students during Orientation.

Accreditation. The Department of Chemistry also administers accreditation examinations for General Chemistry I, II, III and Organic Chemistry I, II, III to entering college students. Students may receive credit on the basis of their performance on these examinations. These examinations are offered only at the beginning of Autumn Quarter.

Grading. Students concentrating in chemistry must receive letter grades (not *P/N* or *P/F* grades) in all courses required in the degree program. In order to qualify for the B.A. or B.S. degree, a GPA of 2.0 or higher (with no grade lower than *C-)* is needed in required chemistry courses (i.e., 20000-level chemistry courses in the preceding list).

Undergraduate Research and the Honors Program. By their junior year, all chemistry concentrators are strongly encouraged to participate in research with a faculty member. For more information on research opportunities, see *chemistry.uchicago.edu/programs.shtml.*

Excellent students who pursue a substantive research project with a faculty member of the Department of Chemistry should plan to submit an honors thesis. Students usually begin this research program during their junior year and continue it through the following summer and their senior year. Students in the honors program are expected to complete their arrangements with the departmental counselor before the end of their junior year and to register for

one quarter of CHEM 29900 (Advanced Research in Chemistry) during their junior or senior years. The B.A. or B.S. degree with special honors in chemistry is awarded to students with an overall GPA of 3.0 or higher who have submitted a creditable honors paper describing their research. The honors paper should be submitted about one month before graduation and must be approved by the Department of Chemistry.

Sample Program. Below is a suggested schedule for completing a B.A. or B.S. degree in chemistry.

First year
CHEM 11101-11201-11301/11102-11202-11302 or 12100-12200-12300
MATH 15100-15200-15300 or equivalent

Second year
CHEM 22000-22100-22200
MATH 20000-20100; STAT 24000 and/or MATH 20200 are strongly recommended
Physics sequence (three quarters)

Third year
CHEM 26100-26200-26700 (if physics is taken in the second year)
CHEM 20100
CHEM 20200, 22300 or 26300 (for B.S.)

Fourth year
CHEM 26100-26200-26700 (if physics is taken in the third year)
CHEM 22300 or 26300 (for B.S.)
CHEM 22700 or 26800 (for B.S.)

Joint Degree Programs. Students who achieve advanced standing through their performance on placement examinations or accreditation examinations may consider the formulation of a four-year degree program that leads to the concurrent award of the B.S. and M.S. degrees in chemistry. Consult the departmental counselor for more information.

Faculty

R. S. Berry, B. Bosnich, L. Butler, R. N. Clayton, P. E. Eaton, K. Freed, R. Gomer, P. Guyot-Sionnest, J. Halpern, R. Haselkorn, C. He, G. Hillhouse, R. Ismagilov, M. Hopkins, R. Jordan, S. Kozmin, K. Y. Lee, D. H. Levy, J. C. Light, D. Mazziotti, M. Mrksich, J. R. Norris, Jr., T. Oka, D. Oxtoby, J. Piccirilli, V. Rawal, S. A. Rice, N. F. Scherer, S. Sibener, H. Yamamoto, N. C. Yang, L. Yu

Courses

In chemistry laboratories, safety goggles must be worn at all times. Students who require prescriptive lenses may wear prescription glasses under goggles; contact lenses may not be worn. Medical exceptions must be obtained from the laboratory director.

11101-11201-11301/11102-11202-11302. General Chemistry I, II, III: Variant A/Variant B. (=ENST 11101-11201-11301/11102-11202-11302) *PQ: Good performance on the mathematics or calculus placement test. The first two courses in this sequence meet the general education requirement in*

the physical sciences. Variants A and B are equivalent presentations of the subject matter of basic chemistry with a difference in focus as detailed below. A discussion of atomic and molecular theories, chemical periodicity, and types of chemical reaction is followed in the first quarter by the chemical importance of pressure and temperature, phase diagrams, and acid-base and heterogeneous equilibria. During the second quarter, the principles of chemical thermodynamics are covered, with applications to chemical and biological systems and to phase equilibria and electrochemistry. In the third quarter, ideas of atomic structure and chemical bonding are studied, along with the special features of liquids and solids and the chemistry of the representative elements. Lab work includes some quantitative measurements, the properties of the important elements and their compounds, and experiments associated with the common ions and their separation and identification by semi-micro methods.

11101-11201-11301. General Chemistry I, II, III: Variant A. Variant A emphasizes the role of chemical and physical processes in the environment, especially in water and in the atmosphere. Variant B has a more traditional organization of basic chemistry. *D. Oxtoby, Autumn; T. Oka, Winter; D. Levy, Spring. L: M. Zhao. Autumn, Winter, Spring.*

11102-11202-11302. General Chemistry I, II, III: Variant B. Variant B is a traditional treatment of the chemical and physical processes studied in basic chemistry. *J. Norris, Autumn; Staff, Winter; P. Guyot-Sionnest, Spring. L: M. Zhao. Autumn, Winter, Spring.*

12100-12200-12300. Honors General Chemistry I, II, III. *PQ: Good performance on the honors chemistry placement test or a score of 5 on the AP chemistry test. The first two courses in this sequence meet the general education requirement in the physical sciences.* The subject matter and general program of CHEM 12100-12200-12300 is the same as that of General Chemistry listed above. However, this course is designed for the student deemed well prepared for a systematic study of chemistry. *K. Y. Lee, Autumn; N. Scherer, Winter; L. Butler, Spring. L: M. Zhao. Autumn, Winter, Spring.*

20100-20200. Inorganic Chemistry I, II. *PQ for CHEM 20100: CHEM 11101-11201-11301 or equivalent, 22000, and concurrent enrollment in 22100. PQ for CHEM 20200: CHEM 20100 and 22200.* The extraordinarily diverse chemistry of the elements is organized in terms of molecular structure, electronic properties, and chemical reactivity. CHEM 20100 concentrates on structure and bonding, solid state chemistry, and selected topics in the chemistry of the main group elements and coordination chemistry. CHEM 20200 focuses on organometallic chemistry, reactions, synthesis, and catalysis, as well as bioinorganic chemistry. *G. Hillhouse, Winter; R. Jordan, Spring.*

21000. Environmental Chemistry. (=ENST 23900, GEOS 23900) *PQ: CHEM 11101-11201, or equivalent; and prior calculus course.* The focus of this course is on the fundamental science underlying issues of local and regional scale pollution. In particular, lifetimes of important pollutants in the air, water, and soils are examined by considering the roles played by photochemistry, surface chemistry, biological processes, and dispersal into surrounding environment. Specific topics include urban air quality, water quality, long-lived organic toxins, heavy metals, and indoor air pollution. Control measures are also considered. *D. Archer. Spring. L.*

22000-22100-22200. Organic Chemistry I, II, III. *PQ: An average grade of* C *or higher in CHEM 11101-11201-11301 or equivalent, or consent of the department. NOTE: Most medical schools require a full academic year of organic chemistry.* The fundamental structures of organic molecules and the spectroscopic methods used to define them are studied. A comprehensive understanding of the reactions and properties of organic molecules (from kinetic, thermodynamic, and mechanistic viewpoints) is developed and applied to the synthesis of organic compounds and to an appreciation of nature's important molecules. *A lab is one afternoon a week in addition to scheduled class time each quarter. V. Rawal, Autumn; S. Kozmin, Winter; M. Mrksich, Spring. L: B. Lin. Autumn, Winter, Spring.*

22300. Intermediate Organic Chemistry. *PQ: A grade of* C *or higher in CHEM 22200, or consent of instructor.* This course provides further in-depth study of structure and reactivity in organic and bioorganic chemistry. It deals with aspects of multistep synthesis, molecular orbital theory, polymers, carbohydrates, peptides, and nucleic acids. *M. Mrksich. Autumn.*

22700. Advanced Organic/Inorganic Laboratory. *PQ: CHEM 20100 and 22300, or consent of instructor.* A project approach is combined with exposure to the more advanced techniques of organic and inorganic chemistry. Multistep synthesis, the synthesis of air-sensitive compounds, advanced chromatographic and spectroscopic characterization of products, and the handling of reactive intermediates are a part of the lab. *G. Hillhouse. Spring.*

26100-26200-26300. Physical Chemistry I, II, III. *PQ: CHEM 11301 or equivalent, and MATH 20100, and PHYS 13300.* The application of physical and mathematical methods to the investigation of chemical systems is studied during this three-quarter sequence.

> **26100. Quantum Mechanics.** This course presents quantum mechanics, the Schrödinger wave equation with exact and approximate methods of solution, angular momentum, and atomic spectra and structure. *D. Mazziotti. Autumn.*
>
> **26200. Thermodynamics.** This course continues the sequence with the study of thermodynamic principles and applications, and statistical mechanics. *L. Butler. Winter.*
>
> **26300. Chemical Kinetics and Dynamics.** This course is a discussion of chemical kinetics and dynamics for processes in gases, in liquids, and at interfaces. *S. Rice. Spring.*

26700. Experimental Physical Chemistry. *PQ: CHEM 26100.* An introduction to the principles and practice of physical chemical measurements. Techniques used in the design and construction of apparatus are discussed in lectures and practice is provided through lab exercises and experiments. Subjects include vacuum techniques, electronics, optics, use of computers in lab instrumentation, materials of construction, and data analysis. *K. Y. Lee. Winter.*

26800. Computational Chemistry and Biology. *PQ: CHEM 26100-26200, or PHYS 19700 and 23400.* The theme for this course is the identification of scientific goals that computation can assist in achieving. The

course is organized around the examination of exemplary problems, such as understanding the electronic structure and bonding in molecules and interpreting the structure and thermodynamic properties of liquids. A special emphasis is placed on problems of a biological nature, such as protein folding, enzyme catalysis, and bioinformatics. The lectures deal with aspects of numerical analysis and with the theoretical background relevant to calculations of the geometric and electronic structure of molecules, molecular mechanics, molecular dynamics, and Monte Carlo simulations. The lab consists of computational problems drawn from a broad range of chemical and biological interests. *K. Freed. Spring.*

29900. Advanced Research in Chemistry. *PQ: Consent of a faculty sponsor and the undergraduate counselor. Open only to chemistry concentrators who are eligible for honors. May be taken either for a letter grade or for* P/N *or* P/F. *Students are required to submit the College Reading and Research Course Form.* Advanced, individually guided re-search. Students may submit a written report covering their research activities for consideration for departmental honors. *Summer, Autumn, Winter, Spring.*

30100. Advanced Inorganic Chemistry. *PQ: CHEM 20100 and 26300, or consent of instructor.* Group theory and its applications in inorganic chemistry are developed. These concepts are used in surveying the chemistry of inorganic compounds from the standpoint of quantum chemistry, chemical bonding principles, and the relationship between structure and reactivity. *M. Hopkins. Autumn.*

30200. Physical Methods in Inorganic Chemistry. *PQ: CHEM 30100.* This course covers theoretical and practical aspects of important physical methods for the characterization of inorganic molecules. Topics may include NMR, IR, RAMAN, EPR, and electronic and photoelectron spectroscopy; electrochemical methods; and single-crystal X-ray diffraction. *M. Hopkins. Winter.*

30400. Organometallic Chemistry. *PQ: CHEM 30100 and 32100, or 32200.* The preparation and properties of organometallic compounds (notably those of the transition elements, their reactions, and the concepts of homogeneous catalysis) are discussed. *B. Bosnich. Spring.*

30600. Chemistry of the Elements. *PQ: CHEM 20100.* The descriptive chemistries of the main-group elements and the transition metals are surveyed from a synthetic perspective, and reaction chemistry of inorganic molecules is systematically developed. *B. Bosnich. Winter.*

30700. Metal Catalysis in Polymer Synthesis. *PQ: CHEM 20200 and 22200.* This course focuses on the application of metal catalysts in polymer synthesis. The scope, mechanisms, stereocontrol aspects, and applications of Ziegler-Natta, metallocene/single-site, ring-opening metathesis, ATRP, and other metal-catalyzed/mediated polymerization reactions are discussed. Key underlying concepts from organomettallic chemistry and polymer science are introduced as appropriate, and the properties and applications of important polymers produced by metal catalysis are discussed. *R. Jordan. Winter.*

30900. Bioinorganic Chemistry. *PQ: CHEM 20200 and 22200.* This course focuses on the various roles of metals in biology. Topics include

coordination chemistry of bioinorganic units, substrate binding and activation, electron-transfer proteins, atom and group transfer chemistry, metal homeostasis, ion channels, metals in medicine, and model systems. *C. He. Autumn.*

32100. Physical Organic Chemistry. *PQ: CHEM 22200 and 26200, or consent of instructor.* We focus on the quantitative aspects of structure and reactivity, molecular orbital theory, and the insight it provides into structures and properties of molecules, stereochemistry, thermochemistry, kinetics, substituent and isotope effects, and pericyclic reactions. *R. Ismagilov. Autumn.*

32200. Organic Synthesis and Structure. *PQ: CHEM 22200 or consent of instructor.* This course presents a close consideration of the mechanisms, applicability, and limitations of the major reactions in organic chemistry, and of stereochemical control in synthesis. *S. Kozmin. Autumn.*

32300. Tactics of Organic Synthesis. *PQ: CHEM 22200 or consent of instructor.* This course presents a dissection of important syntheses of complex natural and unnatural products and covers such topics as synthesis planning and methodology, the logic of synthesis. *V. Rawal. Winter.*

32400. Physical Organic Chemistry II. *PQ: CHEM 32100.* Topics include the mechanisms and fundamental theories of free radicals and the related free radical reactions, biradical and carbene chemistry, and pericyclic and photochemical reactions. *L. Yu. Winter.*

32500. Bioorganic Chemistry. A goal of this course is to relate chemical phenomena with biological activities. We cover two main areas: (1) chemical modifications of biological macromolecules and their potential effects; and (2) the application of spectroscopic methods to elucidate the structure and dynamics of biologically relevant molecules. *J. Piccirilli. Spring.*

32600. Protein Fundamentals. (=BCMB 30400) *PQ: BCMB 30100 or consent of instructor.* The focus of this course is on the physico-chemical phenomena that define protein structure and function. Topics include (1) the interactions/forces that define polypeptide conformation; (2) the principles of protein folding, structure, and design; and (3) the concepts of molecular recognition and enzyme catalysts. *J. Piccirilli. Autumn.*

32800. Surface Chemistry. *PQ: CHEM 22200, and 26300.* This course introduces the organic chemistry of surfaces and interfaces with an emphasis on Langmuir-Blodgett films and self-assembled monolayers. Methods for the synthesis and characterization of these interfaces are presented. Recent literature is surveyed to establish the relationships between interfacial structure and properties, and to understand the design of functional interfaces. *Not offered 2002-03.*

32900. Polymer Chemistry. *PQ: CHEM 22200 and 26300.* This course introduces a broad range of polymerization reactions and discusses their mechanisms and kinetics. New concepts of polymerization and new materials of current interest are introduced and discussed. We also discuss the physical properties of polymers, ranging from thermal properties to electrical and optical properties in both a solution state and a solid state. Our emphasis is on structure/property relationship. *L. Yu. Spring.*

33000. Complex Chemical Systems. *PQ: CHEM 22200 and MATH 20100, or consent of instructor.* This course describes chemical systems in which nonlinear kinetics lead to unexpected (emergent) behavior of the system. Autocatalytic and spatiotemporal pattern forming systems are covered, and their importance in the development and function of living systems are discussed. *R. Ismagilov. Winter.*

36100. Wave Mechanics and Spectroscopy. *PQ: CHEM 26300.* The introductory concepts, general principles, and applications of wave mechanics to spectroscopy are presented. *D. Levy. Autumn.*

36200. Quantum Mechanics. *PQ: CHEM 36100.* A formal development of quantum mechanics is presented, including operators, matrix mechanics, and perturbation methods. The theory is applied to the description of the electronic structure of atoms and molecules. *K. Freed. Winter.*

36300. Statistical Mechanics. *PQ: CHEM 26200.* The general theory of statistical mechanics is applied to thermodynamics. Various perfect systems, some special distributions, and special topics are examined. *S. Rice. Winter.*

36400. Chemical Thermodynamics. *PQ: CHEM 26200.* In this course, the thermodynamics of equilibrium systems is discussed. *N. Scherer. Autumn.*

36500. Chemical Dynamics. *PQ: CHEM 36100 required; 36300 recommended.* This course develops a molecular-level description of chemical kinetics, reaction dynamics, and energy transfer in both gases and liquids. Topics include potential energy surfaces, collision dynamics and scattering theory, reaction rate theory, collisional and radiationless energy transfer, molecule-surface interactions, Brownian motion, time correlation functions, and computer simulations. *S. Sibener. Spring.*

36800. Advanced Computational Chemistry and Biology. *PQ: CHEM 26100-26200, or PHYS 19700 and 23400. Concentrators may not use this course to meet requirements for the B.S. degree.* The theme for this course is the identification of scientific goals that computation can assist in achieving. The course is organized around the examination of exemplary problems, such as understanding the electronic structure and bonding in molecules and interpreting the structure and thermodynamic properties of liquids. The lectures deal with aspects of numerical analysis and with the theoretical background relevant to calculations of the geometric and electronic structure of molecules, molecular mechanics, molecular dynamics, and Monte Carlo simulations. The lab consists of computational problems drawn from a broad range of chemical and biological interests. *K. Freed. Spring.*

38700. Biophysical Chemistry. This course develops a physicochemical description of biological systems. Topics include macromolecules, fluid-phase lipid-bilayer structures in aqueous solution, biomembrane mechanics, control of biomolecular assembly, and computer simulations of biomolecular systems. *Not offered 2002-03.*