

# Chemistry

*Departmental Counselor:*

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## 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 in chemistry are designed to provide a broad foundation in the three principal branches of the 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

The principal distinction between the B.A. and B.S. programs is the number of chemistry courses required.

**Program Requirements: B.A.** 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 typically required for the B.S. degree.

## Summary of Requirements

<i>General Education</i>		CHEM 11101-11201 or 11102-11202 or equivalent†* MATH 13100-13200 or higher†
<i>Major</i>	1	CHEM 11301 or 11302 or equivalent†*
	1	MATH 13300 or higher† or STAT 22000 or higher
	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/ 22000-23100-23200	3 CHEM 22000-22100-22200/ 22000-23100-23200
2 CHEM 26100-26200	1 CHEM 23300
<u>1</u> CHEM 26700	3 CHEM 26100-26200-26300
14	1 CHEM 26700
	<u>1</u> CHEM 22700 or 26800
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† *Credit may be granted by examination.*

\* *See following sections on Advanced Placement and Honors Chemistry Placement Test.*

NOTE: The three-quarter sequence MATH 20300-20400-20500 may be substituted for 20000; and MATH 27000 and 27300 may be substituted for 20100. MATH 25000 is recommended for chemistry majors who plan to pursue advanced study in physical chemistry.

**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 12200-12300).

Students who complete Honors General Chemistry (CHEM 12200-12300) use one AP credit as the first quarter of the general chemistry requirement. These students forgo two quarters of AP credit. Students who complete CHEM 12200, but not 12300, forgo one quarter of AP credit and apply two quarters of AP credit to CHEM 11101-11301. Students who complete CHEM 12300, but not 12200, forgo one quarter of AP credit and apply two quarters of AP credit to CHEM 11101-11201.

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

Students who complete Honors General Chemistry (CHEM 12200-12300) receive one placement credit to be used as the first quarter of the general chemistry requirement. Students who complete CHEM 12200, but not 12300, complete the three-quarter requirement with registration for CHEM 11201-11301/11202-11302.

**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. Only incoming first-year and transfer students are eligible to take these examinations, which are offered at the beginning of Autumn Quarter. Students may receive credit on the basis of their performance on accreditation examinations.

**Grading.** 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. Students majoring in chemistry must receive quality grades in all courses required in the degree program. Only grades of C- or higher constitute passing work. Nonmajors may take chemistry courses on a *P/F* basis.

**Undergraduate Research and Honors.** By their third year, students majoring in chemistry are strongly encouraged to participate in research with a faculty member. For more information on research opportunities, visit [chemistry.uchicago.edu/undergrad.shtml](http://chemistry.uchicago.edu/undergrad.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 based on their work. Students usually begin this research program during their third year and continue through the following summer and their fourth year. Students who wish to be considered for honors are expected to complete their arrangements with the departmental counselor before the end of their third year and to register for one quarter of CHEM 29900 (Advanced Research in Chemistry) during their third or fourth years.

To be eligible to receive honors, students in the B.A. or B.S. degree program in chemistry must write a creditable honors paper describing their research. The paper must be submitted before the deadline established by the departmental counselor and must be approved by the Department of Chemistry. In addition, an oral presentation of the research is required. The research paper or project used to meet this requirement may not be used to meet the B.A. paper or project requirement in another major.

To earn a B.A. or B.S. degree with honors in chemistry, students must also have an overall GPA of 3.0 or higher.

**Sample Program.** A suggested schedule for completing a B.A. or B.S. degree in chemistry follows.

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

*Second year* CHEM 22000-22100-22200 or CHEM 22000-23100-  
23200  
MATH 20000-20100  
Physics sequence (three quarters)

<i>Third year</i>	CHEM 26100-26200-26700 (if physics is taken in the second year) CHEM 20100 CHEM 20200, 23300 or 26300 (for B.S.)
<i>Fourth year</i>	CHEM 26100-26200-26700 (if physics is taken in the third year) CHEM 23300 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, A. Dinner, P. E. Eaton, K. Freed, P. Guyot-Sionnest, J. Halpern, R. Haselkorn, C. He, G. Hillhouse, M. Hopkins, R. Ismagilov, R. Jordan, S. Kent, S. Kozmin, K. Y. C. Lee, D. H. Levy, J. C. Light, D. Mazziotti, M. Mrksich, J. R. Norris, Jr., T. Oka, J. Piccirilli, V. Rawal, S. A. Rice, N. F. Scherer, S. Sibener, H. Yamamoto, N. C. Yang, J. Yin, L. Yu

## Courses: Chemistry (CHEM)

*In chemistry labs, 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. Exceptions for medical reasons must be obtained from the lab director.*

**11101-11201-11301/11102-11202-11302. General Chemistry I, II, III (Variant A/Variant B).** *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 shown in following descriptions. Both three-quarter sequences cover atomic and molecular theories, chemical periodicity, chemical reaction, the chemical importance of pressure and temperature, phase diagrams, acid-base and heterogeneous equilibria, and chemical thermodynamics, as well as applications to chemical and biological systems and to phase equilibria and electrochemistry. Ideas of atomic structure and chemical bonding are also 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).** (=ENST 11101-11201-11301) *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. Variant A is presented at the same level as Variant B, but it takes on a more synthetic perspective in the third quarter. S. Sibener, Autumn; K. Y. C. Lee, Winter; L. Yu, 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. It also takes on a more physical perspective in the third quarter. *J. R. Norris, Jr., Autumn; N. F. Scherer, Winter; K. Freed, Spring. L: M. Zhao, Autumn, Winter, Spring.*

**12200-12300. Honors General Chemistry II, III.** *PQ: Good performance on the honors chemistry placement test or a score of 5 on the AP chemistry test. These two courses, together with one quarter of credit from AP or placement, constitute a full year of general chemistry. Students who choose this option will have met the general education requirement in the physical sciences.* The subject matter and general program of CHEM 12200-12300 is similar to that of General Chemistry listed previously. However, this accelerated course on the subject matter is designed for the student deemed well prepared for a systematic study of chemistry. *Autumn, Winter. L: M. Zhao, D. Mazziotti, Autumn; A. Dinner, Winter.*

**20100-20200. Inorganic Chemistry I, II.** *PQ for CHEM 20100: 11101-11201-11301 or equivalent, 22000, and concurrent enrollment in 22100. PQ for 20200: 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.*

**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. (Students who receive a grade of B or higher in 22000 have the option of moving into honors organic chemistry for winter/spring. See following listing for 23100-23200.) 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. M. Mrksich, Autumn; S. Kozmin, Winter; J. Piccirilli, Spring. L: B. Lin Kendall. Autumn, Winter, Spring.*

**22700. Advanced Organic/Inorganic Laboratory.** *PQ: CHEM 20100 and 23300, 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. *Spring.*

**23100-23200. Honors Organic Chemistry II, III.** *PQ: A grade of B or higher in CHEM 22000, or consent of instructor.* This sequence is a more in-depth version of CHEM 22100-22200 that is intended for students who have demonstrated good performance in 22000. The subject matter is similar but at a more advanced level. *R. Ismagilov, Winter; H. Yamamoto, Spring. L: B. Lin Kendall.*

**23300. Intermediate Organic Chemistry: Biological Chemistry.** *PQ: A grade of C or higher in CHEM 22200 or 23200, or consent of instructor.* This course addresses the chemical foundations of the biosynthetic pathways for amino acids, carbohydrates, lipids, and natural products. We emphasize reaction mechanisms in the biosynthesis of these naturally occurring molecules. *M. Mrksich. Autumn.*

**26100-26200-26300. Physical Chemistry I, II, III.** *PQ: CHEM 11301 or equivalent; 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. H. Levy. Autumn.*

**26200. Thermodynamics.** This course continues the sequence with the study of thermodynamic principles and applications, as well as 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. *K. Y. C. Lee. Spring.*

**26700. Experimental Physical Chemistry.** *PQ: CHEM 26100.* This course introduces 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 covered include vacuum techniques, electronics, optics, use of computers in lab instrumentation, materials of construction, and data analysis. *J. R. Norris, Jr. Winter. L.*

**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. *A. Dinner. Spring. L.*

**29900. Advanced Research in Chemistry.** *PQ: Consent of a faculty sponsor and the undergraduate counselor. Open only to chemistry majors who are eligible for honors. May be taken either for a quality grade or P/F. Students are required to submit the College Reading and Research Course Form.* Students conduct advanced, individually guided research. 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. Synthesis and 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. *R. Jordan. Winter.*

**30400. Organometallic Chemistry.** *PQ: CHEM 20100.* The preparation and properties of organometallic compounds (notably those of the transition elements, their reactions, and the concepts of homogeneous catalysis) are discussed. *G. Hillhouse. Winter.*

**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. *C. He. Spring.*

**30900. Bioinorganic Chemistry.** *PQ: CHEM 20200 and 22200/23200.* This course covers 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.*

**31100. Supramolecular Chemistry.** This course develops the concepts of supramolecular chemistry (both organic and metal-based systems) and its applications. Coordination chemistry is introduced as a background to metal-based supramolecular systems. The chemistry and physical properties of transition

metal complexes are presented, including crystal field theory, molecular orbital theory, magnetism, and electronic spectra. The mechanisms by which molecular motors operate are presented and reference is made to synthetic systems that attempt to emulate biological molecular motors. *Spring. Offered 2007-08; not offered 2006-07.*

**32100. Physical Organic Chemistry I.** *PQ: CHEM 22200/23200 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. *L. Yu. Autumn.*

**32200. Organic Synthesis and Structure.** *PQ: CHEM 22200/23200 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. *V. Rawal. Autumn.*

**32300. Tactics of Organic Synthesis.** *PQ: CHEM 22200/23200 or consent of instructor.* This course presents a discussion of the important classes for organic transformation. Topics include carbon-carbon bond formation; oxidation; and reduction using a metal, non-metal, or acid-base catalyst. We also cover design of the reagents and the scope and limitation of the processes. *H. Yamamoto. 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. *S. Kozmin. 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. Yin. 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.*

**32900. Polymer Chemistry.** *PQ: CHEM 22200/23200 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. *Offered 2007-08; not offered 2006-07.*



**33000. Complex Chemical Systems.** PQ: CHEM 22200/23200 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. Offered 2007-08; not offered 2006-07.

**33100. New Synthetic Reactions and Catalysts.** PQ: CHEM 23300. This course presents recent highlights of new synthetic reactions and catalysts for efficient organic synthesis. Mechanistic details as well as future possibilities are discussed. Spring. Offered 2007-08; not offered 2006-07.

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

**36200. Quantum Mechanics.** PQ: CHEM 36100. This course builds upon the concepts introduced in CHEM 36100 with greater detail provided for the role of quantum mechanics in chemical physics. D. H. Levy. 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. D. Mazziotti. Winter.

**36400. Chemical Thermodynamics.** PQ: CHEM 26200. The thermodynamics of equilibrium systems is discussed in this course. N. F. 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. L. Butler. Spring.

**36800. Advanced Computational Chemistry and Biology.** PQ: CHEM 26100-26200, or PHYS 19700 and 23400. This course may not be used 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. A. Dinner. Spring. L.

**36900. Materials Chemistry.** This course covers structural aspects of colloidal systems, surfactants, polymers, diblock copolymers, and self-assembled monolayers. We also cover the electronic properties associated with organic conducting polymers, organic light-emitting devices, and transistors. More novel topics of molecular electronics, nanotubes, quantum dots, and magnetic systems are also covered. The aim of the course is to provide a broad perspective of the various contributions of chemistry to the development of functional materials. *P. Guyot-Sionnest. 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. *K. Y. C. Lee. Offered 2007-08; not offered 2006-07.*