Chemistry

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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 BA and BS 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 BS degree offers a more intensive program of study. The BA 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 BA and BS programs is the number of chemistry courses required.

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

Program Requirements: BS 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 BS degree.

Summary of Requirements

General Education		CHEM 11100-11200 or equivalent†*
		MATH 15100-15200 or 16100-16200†, or a grade of *A-* or higher in 13100-13200
Major	1	CHEM 11300 or equivalent†*
	1	MATH 15300 or 16300 or 19620†, or a grade of *A-* or higher in 13300
	2	MATH 20000-20100
	3	PHYS 13100-13200-13300 or higher†

plus the following requirements:

BA		BS	
1	CHEM 20100	2	CHEM 20100-20200
3	CHEM 22000-22100-22200/ 23000-23100-23200	3	CHEM 22000-22100-22200/ 23000-23100-23200
2	CHEM 26100-26200	1	CHEM 23300
1	CHEM 26700	3	CHEM 26100-26200-26300
14		1	CHEM 26700
		1	CHEM 22700 or 26800
		18	

† *Credit may be granted by examination.*
* *See following sections on Advanced Placement and Accreditation Examinations.*

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 19620 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 Comprehensive General Chemistry I, II, III (CHEM 11100-11200-11300). Many such students elect to take Honors General Chemistry (CHEM 12100-12200-12300). Students who complete one to three quarters of Comprehensive General Chemistry or Honors General Chemistry forgo partial or full AP credit.

Accreditation. The Department of Chemistry also administers accreditation examinations for Comprehensive 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 BA or BS 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. Nonmajors may take chemistry courses on a *P/F* basis; only grades of *C-* or higher constitute passing work.

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.*

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 BA or BS 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 BA paper or project requirement in another major.

To earn a BA or BS 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 BA or BS degree in chemistry follows.

First year	CHEM 11100-11200-11300 or 12100-12200-12300 MATH 15100-15200-15300 or 19620 or equivalent
Second year	CHEM 22000-22100-22200 or CHEM 23000-23100-23200 MATH 20000-20100 Physics sequence (three quarters)
Third year	CHEM 26100-26200-26700 (if physics is taken in the second year) CHEM 20100 CHEM 20200, 23300 or 26300 (for BS)
Fourth year	CHEM 26100-26200-26700 (if physics is taken in the third year) CHEM 23300 or 26300 (for BS) CHEM 22700 or 26800 (for BS)

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 BS and MS degrees in chemistry. Consult the departmental counselor for more information.

Faculty

R. S. Berry, L. Butler, R. N. Clayton, A. Dinner, P. E. Eaton, G. Engel, 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, D. Talapin, H. Yamamoto, 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.

10100-10200-10300. Introductory General Chemistry I, II, III. *PQ: Enrollment limited to first-year students. Enrollment by placement only. The first two courses in this sequence meet the general education requirement in the physical sciences. Not recommended for students majoring in Chemistry or Biological Chemistry.* A systematic introduction to chemistry for beginning students in chemistry or for those whose exposure to the subject has been moderate. Apart from one discussion session per week and a laboratory component, special emphasis on scientific problem-solving skills is made through two additional structured learning sessions per week devoted to quantitative reasoning. *Attendance at discussion, structured learning, and laboratory sessions is mandatory.* The three-quarter sequence covers atomic and molecular theories, chemical periodicity, chemical reactivity and bonding, chemical equilibria, acid-base equilibria, solubility equilibria, phase equilibria, thermodynamics, electrochemistry, kinetics, quantum mechanics, and nuclear chemistry. Examples are drawn from chemical, biological, and materials systems. The laboratory portion includes an introduction to quantitative measurements, investigation of the properties of the important elements and their compounds, and experiments associated with the common ions and their separation and identification. *L. Butler, Autumn; K. Y. C. Lee, Winter; L. Yu, Spring. L: M. Zhao.*

11100-11200-11300. Comprehensive General Chemistry I, II, III. *PQ: Good performance on the mathematics/calculus and chemistry placement tests. Enrollment by placement only. The first two courses in this sequence meet the general education requirement in the physical sciences.* A comprehensive survey of modern descriptive, inorganic, and physical chemistry for students with a good secondary school exposure to general chemistry. One discussion session per week and a laboratory component. *Attendance at discussion and laboratory sessions is mandatory.* The three-quarter sequence covers atomic and molecular theories, chemical periodicity, chemical reactivity and bonding, chemical equilibria, acid-base equilibria, solubility equilibria, phase equilibria, thermodynamics, electrochemistry, kinetics, quantum mechanics, and nuclear chemistry. Examples are drawn from chemical, biological, and materials systems. The laboratory portion includes an introduction to quantitative measurements, investigation of the properties of the important elements and their compounds, and experiments associated with the common ions and their separation and identification. *S. Sibener, Autumn; P. Guyot-Sionnest, Winter; S. Kozmin, Spring. L: M. Zhao.*

12100-12200-12300. Honors General Chemistry I, II, III. *PQ: Good performance on the chemistry placement test or a score of 5 on the AP chemistry test. Enrollment by placement only. The first two courses in this sequence meet the general education requirement in the physical sciences.* The subject matter and general program of this sequence is similar to that of the Comprehensive General Chemistry sequence. However, this accelerated course on the subject matter is designed for students deemed well prepared for a thorough and systematic study of chemistry. Introductory materials covered in the Comprehensive General Chemistry sequence are not part of the curriculum for this sequence; instead, special topics are included in each quarter to provide an in-depth examination of various subjects of current interest in chemistry. One discussion session per week and a laboratory component. *Attendance at discussion and laboratory sessions is mandatory. G. Engel, Autumn; A. Dinner, Winter; N. Scherer, Spring. L: M. Zhao.*

20100-20200. Inorganic Chemistry I, II. *PQ for 20100: CHEM 11100-11200-11300 or equivalent, 22000 and 22100, or concurrent enrollment in 22100 or equivalent. PQ for 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.*

22000-22100-22200. Organic Chemistry I, II, III. *PQ: An average grade of* C *or higher in CHEM 10100-10200-10300 or CHEM 11100-11200-11300 or CHEM 12100-12200-12300, a 5 on the AP Chemistry exam, or consent of the department. (Students who receive a grade of* B+ *or higher in CHEM 22000 have the option of moving into honors organic chemistry for Winter/Spring. See following listing for CHEM 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. H. Yamamoto, Autumn; V. Rawal, Winter; J. Piccirilli, Spring. L: V. Keller.*

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. *C. He. Spring.*

23000-23100-23200. Honors Organic Chemistry I, II, III. *PQ: An average grade of* B+ *or higher in CHEM 11100-11200-11300 or equivalent, a 5 on the AP Chemistry exam, or consent of the department, and/or via placement exam. Students who have taken CHEM 22000 or 22100 with an average grade of* B+ *or higher may petition the instructor to move into the Honors sequence. 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. R. Ismagilov, Autumn; M. Mrksich, Winter; S. Kent, Spring. L: V. Keller.*

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. *J. Yin. Autumn.*

26100-26200-26300. Physical Chemistry I, II, III. *PQ: CHEM 11300 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. Mazziotti. 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. *G. Engel. 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. We examine problems such as understanding the electronic structure and bonding in molecules, interpreting the structure and thermodynamic properties of liquids, 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. *Z. Gasyna. Spring. L.*

29900. Advanced Research in Chemistry. *PQ: Consent of a faculty sponsor and the undergraduate counselor. Open only to students majoring in chemistry who are eligible for honors. Available for either quality grades or for* P/F *grading. 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. Autumn.*

30500. Nanoscale Materials. *PQ: CHEM 20200 and 26300, or consent of instructor.* This course provides an overview of nanoscale phenomena in metals, semiconductors, and magnetic materials (e.g., the fundamental aspects of quantum confinement in semiconductors and metals, superparamagnetism in nanoscale magnets, electronic properties of nanowires and carbon nanotubes, surface plasmon resonances in nanomaterials, photonic crystals). Special attention is paid to preparative aspects of nanomaterials, colloidal and gas-phase syntheses of nanoparticles, nanowires, and nanotubes. Engineered nanomaterials and their assemblies are considered promising candidates for a variety of applications, from solar cells, electronic circuits, light-emitting devices, and data storage to catalysts, biological tags, cancer treatments, and drug delivery. The course covers state-of-the art in these and other areas. Finally, the course provides an overview of the experimental techniques used for structural characterization of inorganic nanomaterials (e.g., electron microscopy, X-ray diffractometry, small-angle X-ray scattering, STM, AFM, Raman spectroscopy). *D. Talapin. 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. *D. Talapin. Winter.*

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. Spring.*

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. *Not offered in 2009–10.*

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 considers the mechanisms, applicability, and limitations of the major reactions in organic chemistry, as well as of stereochemical control in synthesis. *V. Rawal. Autumn.*

32300. Tactics of Organic Synthesis. *PQ: CHEM 22200/23200 or consent of instructor.* This course discusses 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. *Not offered in 2009–10.*

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. *Not offered in 2009–10.*

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. *Not offered in 2009–10.*

33200-33300. Chemical Biology I, II. *PQ: Basic knowledge of organic chemistry and biochemistry.* This course emphasizes the concepts of physical organic chemistry (e.g., mechanism, molecular orbital theory, thermodynamics, kinetics) in a survey of modern research topics in chemical biology. Topics, which are taken from recent literature, include the roles of proteins in signal transduction pathways, the biosynthesis of natural products, strategies to engineer cells with novel functions, the role of spatial and temporal inhomogeneities in cell function, and organic synthesis and protein engineering for the development of molecular tools to characterize cellular activities. *J. Yin, Winter; M. Mrksich, Spring.*

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 roles in the development and function of living systems are discussed. *Not offered in 2009–10.*

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 and future possibilities are discussed. *Not offered in 2009–10.*

33400. High-Throughput Synthesis and Screening. The course focuses on discovery of reactions, bioactive compounds, and materials by construction of chemical libraries and screening them for desired properties. *S. Kozmin. Spring.*

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. Mazziotti. Winter.*

36300. Statistical Thermodynamics. *PQ: CHEM 26100-26200.* This course covers the thermodynamics and introductory statistical mechanics of systems at equilibrium. *N. Scherer. Autumn.*

36400. Advanced Statistical Mechanics. *PQ: CHEM 36300 or equivalent.* Topics may include statistics of quantum mechanical systems, weakly and strongly interacting classical systems, phase transitions and critical phenomena, systems out of equilibrium, and polymers. *A. Dinner. Winter.*

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. This course may not be used to meet requirements for the BS 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. *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. *Not offered in 2009–10.*

37100. Advanced Spectroscopies. This linear and nonlinear spectroscopy course includes notions on matter-radiation interaction, absorption, scattering, and oscillator strength. They are applied mostly with the optical range, but we briefly touch upon microwave (NMR, ESR) and X-rays at the extreme. We cover nonlinear optical processes such as coherent Raman, harmonic, and sum-frequency; induced transparency; slow light; and X-ray generation. We also cover coherent and incoherent dynamical probes, such as pump-probe, echos, and two-dimensional spectroscopy. *Not offered in 2009–10.*

37200. Statistical Mechanics of Polymers/Glasses. *PQ: CHEM 36400 or equivalent.* The course material is designed to describe the basic statistical mechanics of polymers in dilute and semi-dilute solutions, including the use of path integrals and renormalization group methods. Lattice models are used to describe polymer melts and blends, focusing on miscibility and the descent into glass formation. *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 in 2009–10.*