Department of Chemistry

Chair
• Viresh Rawal

Professors
• Laurie Jeanne Butler
• Aaron Dinner
• Gregory Engel
• Philippe M. Guyot Sionnest
• Chuan He
• Michael D. Hopkins
• Richard F. Jordan
• Stephen Kent, Biochemistry & Molecular Biology
• Sergey Kozmin
• Yamuna Krishnan
• Ka Yee Christina Lee
• Donald H. Levy
• Wenbin Lin
• David Mazziotti
• Joseph Piccirilli, Biochemistry & Molecular Biology
• Viresh Rawal
• Benoit Roux, Biochemistry & Molecular Biology
• Norbert F. Scherer
• Steven J. Sibener
• Scott Snyder
• Dmitri Talapin
• Andrei Tokmakoff
• Gregory Voth
• Luping Yu

Assistant Professors
• John Anderson
• Bryan Dickinson
• Jared Lewis
• Raymond Moellering
• Bozhi Tian
• Suriyanarayanan Vaikuntanathan
• Yossi Weizmann

Emeritus Faculty
The Ph.D. program in the Department of Chemistry offers wide opportunity and unusual flexibility for advanced study and research, and is designed to encourage individuality, independence, and excellence in students. Most students select their research advisor by winter quarter of their first year and are engaged in research by the spring quarter. The department has neither a system of cumulative examinations nor a written major examination. There are relatively few course requirements and great flexibility as to which courses may be taken.

In the Division of the Physical Sciences barriers between departments are low. Students in the Department of Chemistry often take courses in other departments and can even earn the degree in chemistry for research that has been done under the supervision of a member of another department. Students are encouraged to fashion special programs of study under the guidance of the faculty.

APPLICATION

A completed application will include undergraduate transcripts, three letters of recommendation, and the results of the GRE examination (to include the advanced test in chemistry). Foreign applicants must also submit the results of the TOEFL or IELTS.

Students are normally admitted beginning with the autumn quarter of each year. The sequential nature of some of our courses makes this the best time to begin graduate studies. Although applications may be considered at any time at the discretion of the admissions committee, students are strongly encouraged to complete their applications by December 15th. The department has no admissions quota and in recent years the entering class has numbered between 20 and 45.

A well defined Master of Science (S.M.) program of appropriate rigor is maintained, but the Department of Chemistry does not offer financial support to students whose degree goal is the master’s degree. This degree is neither a prerequisite for, nor a forerunner of, the Ph.D. degree, although it may be acquired along the way if a student so desires.

The Department of Chemistry participates actively in the Medical Scientist Training Program (MSTP) administered by the Pritzker School of Medicine at the
University of Chicago. MSTP is a structured six year program leading to both the M.D. degree and the Ph.D. in chemistry. Full tuition and a stipend are awarded for the six year period. MSTP is funded by the National Institute of General Medical Sciences and is open only to U.S. citizens.

**FINANCIAL SUPPORT**

All students admitted to the Ph.D. program are offered financial support. Generally this takes the form of a first year teaching assistantship which provides a complete merit tuition scholarship and pays a competitive monthly stipend. Teaching assistants are usually assigned to one of the undergraduate laboratory courses. Duties involve supervising one class section (13-18 students) for one afternoon per week, holding a discussion session and office hours, and assisting with grading. The total time required is about fifteen hours per week.

By the end of the third quarter students have usually selected their research supervisor. An appointment as a research assistant (stipend plus tuition) normally continues throughout the period of research.

There are several special supplemental fellowships and scholarships offered by the department and the University. All students seeking admission are automatically considered in the competition for these awards. No separate application is required. Students are urged to compete for the many national and other external fellowships available.

**ADVANCED DEGREES**

The department administers basic examinations in the fields of inorganic, organic, and physical chemistry in the autumn, winter, and spring quarters. Graduate students are expected to take these examinations upon entering the department. Deficiencies evidenced by these examinations must be remedied and the examinations passed prior to the end of the third quarter of residence (not counting summer quarter).

In the first year, students must satisfactorily complete nine courses. At least six of these must be 30000 level courses from the offerings of the Department of Chemistry or of related departments in the Divisions of the Physical and the Biological Sciences, and of these six courses, at least two shall be in different areas of chemistry, e.g., inorganic, organic, or physical chemistry. For this purpose, inorganic chemistry courses are defined as Chemistry 30100–31100, organic chemistry courses as Chemistry 32100–33400, and physical chemistry courses as Chemistry 36100–39100. Grades of C or better are expected. The remaining three courses may include Chemistry 35000 and/or 40000 level chemistry research courses; however, one may not register for these courses during the autumn quarter. An advisor assists students in formulating programs of study that will best satisfy personal needs and departmental requirements. Courses taken outside the department to satisfy the first year requirements must be approved by the advisor.

Students who have completed all courses with grades of C or better (P in research courses) may be recommended for the S.M. degree; these students may, at the
discretion of a faculty member, be required to submit a paper on their work in CHEM 35000 or a 40000 level research course.

At the end of the spring quarter in the first year, the faculty review the student's overall record. Course performance is a major part of this review; a B average or better in all 30000 level courses (excluding CHEM 35000) is expected. At this time the department will advise students whether they are qualified to continue studies and to prepare for the Ph.D. candidacy examination described below. A student seeking admission to Ph.D. candidacy must take the candidacy examination before the end of his or her fifth quarter in residence (normally October for this purpose; summer quarter is counted as a quarter in residence). This examination is based on the student's written research prospectus and on the discussion of scientific papers selected by the examining committee. The student presents the research prospectus to the committee, and must be prepared to discuss the relevant chemical literature, progress to date, plans for future work, and the relationship of the research to other chemical problems. The student is expected to conduct a critical analysis of the scientific papers selected by the committee.

The faculty review the recommendations of the candidacy examining committee and, after consideration of the student's academic record, vote on whether or not to recommend that the student be admitted to candidacy. All candidates for the Ph.D. degree are required to participate in some form of teaching. Normally this involves serving as a teaching assistant for three quarters.

The Ph.D. degree is granted upon satisfactory completion of scholarly research work, presented in a written thesis, discussed in a public seminar, and defended orally before a faculty committee.

Students should especially note the following:

- It is the responsibility of the individual research sponsor to monitor the progress of a student's research. Unsatisfactory progress may result in termination of financial support and/or dismissal from the Ph.D. program.
- The department will recommend formal admission to candidacy as soon as the student has:
  - Satisfied the basic examination requirement
  - Satisfied the course requirements
  - Passed the candidacy examination
  - Demonstrated satisfactory progress in research and teaching
- Students should consider satisfying any or all course requirements by taking proficiency examinations. Application to take a proficiency examination should be made directly to the person who will be teaching the particular course. The examinations will be administered during the first week of the quarter in which the course is offered. No stigma is attached to failing a proficiency examination.
CHEMISTRY COURSES

CHEM 30100. Advanced Inorganic Chemistry. 100 Units.
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.
Instructor(s): W. Lin Terms Offered: Autumn
Prerequisite(s): CHEM 20100 and CHEM 26100

CHEM 30200. Synthesis and Physical Methods in Inorganic Chemistry. 100 Units.
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.
Instructor(s): W. Lin Terms Offered: Winter
Prerequisite(s): CHEM 30100

CHEM 30400. Organometallic Chemistry. 100 Units.
This course covers preparation and properties of organometallic compounds (notably those of the transition elements, their reactions, and the concepts of homogeneous catalysis).
Instructor(s): J. Lewis Terms Offered: Autumn
Prerequisite(s): CHEM 20100

CHEM 30500. Nanoscale Materials. 100 Units.
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).
Instructor(s): B. Tian Terms Offered: Not offered in 2015 - 2016.
Prerequisite(s): CHEM 20200 and 26300, or consent of instructor

CHEM 30600. Chemistry of the Elements and Materials. 100 Units.
This course surveys the descriptive chemistries of the main-group elements and the transition metals from a synthetic perspective, and reaction chemistry of inorganic molecules is systematically developed.
Instructor(s): J. Anderson Terms Offered: Winter
Prerequisite(s): CHEM 20100
CHEM 30900. Bioinorganic Chemistry. 100 Units.
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.
Instructor(s): C. He Terms Offered: Spring
Prerequisite(s): CHEM 20200 and 22200/23200

CHEM 31100. Supramolecular Chemistry. 100 Units.
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.
Terms Offered: Not offered in 2015–16
Prerequisite(s): CHEM 20200 and 22200/23200

CHEM 32100. Physical Organic Chemistry I. 100 Units.
This course focuses 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.
Instructor(s): L. Yu Terms Offered: Autumn
Prerequisite(s): CHEM 22200/23200 and 26200, or consent of instructor

CHEM 32200. Organic Synthesis and Structure. 100 Units.
This course considers the mechanisms, applicability, and limitations of the major reactions in organic chemistry, as well as of stereochemical control in synthesis.
Instructor(s): S. Kozmin Terms Offered: Autumn
Prerequisite(s): CHEM 22200/23200 or consent of instructor

CHEM 32300. Strategies and Tactics of Organic Synthesis. 100 Units.
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.
Instructor(s): S. Snyder Terms Offered: Winter
Prerequisite(s): CHEM 22200/23200 or consent of instructor

CHEM 32400. Physical Organic Chemistry II. 100 Units.
Topics covered in this course include the mechanisms and fundamental theories of free radicals and the related free radical reactions, biradical and carbene chemistry, and pericyclic and photochemical reactions.
Terms Offered: Not offered in 2015–16
Prerequisite(s): CHEM 32100
CHEM 32500. Bioorganic Chemistry. 100 Units.
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.
Terms Offered: Not offered in 2015–16
Equivalent Course(s): BCMB 32500

CHEM 32900. Polymer Chemistry. 100 Units.
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.
Terms Offered: Not offered in 2015–16
Prerequisite(s): CHEM 22200/23200 and 26300

CHEM 33000. Complex Chemical Systems. 100 Units.
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.
Terms Offered: Not offered in 2015–16
Prerequisite(s): CHEM 22200/23200 and MATH 20100, or consent of instructor

CHEM 33100. New Synthetic Reactions and Catalysts. 100 Units.
This course presents recent highlights of new synthetic reactions and catalysts for efficient organic synthesis. Mechanistic details and future possibilities are discussed.
Terms Offered: Not offered in 2015–16
Prerequisite(s): CHEM 23300

CHEM 33200-33300. Chemical Biology I-II.
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.
CHEM 33200. Chemical Biology I. 100 Units.
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.
 Instructor(s): B. Dickinson Terms Offered: Autumn
 Prerequisite(s): Basic knowledge of organic chemistry and biochemistry

CHEM 33300. Chemical Biology II. 100 Units.
No description available.
Instructor(s): R. Moellering Terms Offered: Winter
Prerequisite(s): Basic knowledge of organic chemistry and biochemistry

CHEM 33300. Chemical Biology II. 100 Units.
No description available.
Instructor(s): R. Moellering Terms Offered: Winter
Prerequisite(s): Basic knowledge of organic chemistry and biochemistry

CHEM 33400. High-Throughput Methods in Chemistry. 100 Units.
The course focuses on discovery of reactions, bioactive compounds, and materials
by construction of chemical libraries and screening them for desired properties.
Terms Offered: Not offered in 2015–16

CHEM 33500. Special Topics in Organic Chemistry. 100 Units.
Instructor(s): S. Kent Terms Offered: Winter 2015
Prerequisite(s): CHEM 22200 or equivalent

CHEM 33500. Special Topics in Organic Chemistry. 100 Units.
Instructor(s): S. Kent Terms Offered: Winter 2015
Prerequisite(s): CHEM 22200 or equivalent

CHEM 33600. Special Topics in Organic Chemistry. 100 Units.
Instructor(s): Y. Weizmann Terms Offered: Spring 2015
Prerequisite(s): CHEM 22200

CHEM 33600. Special Topics in Organic Chemistry. 100 Units.
Instructor(s): Y. Weizmann Terms Offered: Spring 2015
Prerequisite(s): CHEM 22200

CHEM 35000. Intro To Research: Chemistry. Var Units.
For course description contact Chemistry.
CHEM 36100. Wave Mechanics and Spectroscopy. 100 Units.
This course presents the introductory concepts, general principles, and applications of wave mechanics to spectroscopy.
Instructor(s): L. Butler Terms Offered: Autumn
Prerequisite(s): CHEM 26300

CHEM 36200. Quantum Mechanics. 100 Units.
This course builds upon the concepts introduced in CHEM 36100 with greater detail provided for the role of quantum mechanics in chemical physics.
Instructor(s): G. Voth Terms Offered: Winter
Prerequisite(s): CHEM 36100

CHEM 36300. Statistical Thermodynamics. 100 Units.
This course covers the thermodynamics and introductory statistical mechanics of systems at equilibrium.
Instructor(s): S. Vaikuntanathan Terms Offered: Autumn
Prerequisite(s): CHEM 26100-26200

CHEM 36400. Advanced Statistical Mechanics. 100 Units.
Topics covered in this course may include statistics of quantum mechanical systems, weakly and strongly interacting classical systems, phase transitions and critical phenomena, systems out of equilibrium, and polymers.
Instructor(s): D. Mazziotti Terms Offered: Winter
Prerequisite(s): CHEM 36300 or equivalent

CHEM 36500. Chemical Dynamics. 100 Units.
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.
Instructor(s): S. Sibener Terms Offered: Spring
Prerequisite(s): CHEM 36100 required; 36300 recommended

CHEM 36800. Advanced Computational Chemistry and Biology. 100 Units.
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. L.
Instructor(s): K. Freed Terms Offered: Not offered in 2015–16
Prerequisite(s): CHEM 26100-26200, or PHYS 19700 and 23400
Note(s): This course may not be used to meet requirements for the BS degree.
CHEM 36900. Materials Chemistry. 100 Units.
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.
Terms Offered: Not offered in 2015–16

CHEM 37100. Advanced Spectroscopies. 100 Units.
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.
Terms Offered: Not offered in 2015–16

CHEM 37200. Statistical Mechanics of Polymers/Glasses. 100 Units.
The material in this course 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.
Terms Offered: Not offered in 2015–16
Prerequisite(s): CHEM 36400 or equivalent

CHEM 38700. Biophysical Chemistry. 100 Units.
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.
Instructor(s): A. Tokmakoff Terms Offered: Spring
Prerequisite(s): CHEM 23300, CHEM 26200.

CHEM 38800. Biophysical Spectroscopy. 100 Units.
Instructor(s): Andrei Tokmakoff Terms Offered: Not offered in 2015 - 2016.
Prerequisite(s): CHEM 26200, CHEM 26700
CHEM 39000. Materials Chemistry I. 100 Units.
This course is an introduction to modern materials chemistry. It covers basic chemistry and physics of condensed systems, such as solids, polymers, and nanomaterials. The electronic structure of metals, semiconductors and magnetically ordered phases will be discussed. We will review optical and electronic properties of different classes of materials using examples of hard and soft condensed matter systems and drawing structure-property relationships for conventional solids, polymers, and nanomaterials. Finally, the course will cover the fundamentals of surface science and material synthesis, applying modern understanding of nucleation and growth phenomena.
Instructor(s): Prof. Dmitri Talapin Terms Offered: Autumn
Prerequisite(s): CHEM 26100, CHEM 26200, and CHEM 26300, or equivalent

CHEM 39100. Materials Chemistry II. 100 Units.
This course will focus on the physical properties and kinetics of materials. The chemically-enabled properties of many different materials will be described, including linear and nonlinear elasticity, piezoelectricity, magnetic phenomena, diffusion and other transport properties, nonlinear optical properties, linear and nonlinear acoustic wave phenomena, and biological impacts. Selected applications associated with these properties will be included. Additionally, the course will discuss complex motion of dislocations and interfaces, morphological evolution, and phase transformations in materials synthesis.
Instructor(s): Prof. Bozhi Tian Terms Offered: Spring
Prerequisite(s): CHEM 26100 and CHEM 26300 or equivalent

CHEM 50000-50001-50002. Advanced Training for Teachers and Researchers in Chemistry-2; Advanced Training for Teachers and Researchers in Chemistry-3; Advanced Training for Teachers and Researchers in Chemistry-I.
This course will extend the traditional two-week departmental TA training into a full year, covering both the materials that are critical to becoming an excellent TA and the skills to produce well-rounded PhD candidates. At the end of this course, students are expected to develop an enhanced understanding and talent of critical thinking, an enriched knowledge base that is critical in solving real-world problems, an improved ability in the consideration and use of innovative pedagogical tools, the ability to transition into independent research, and effective skills in preparing high-quality written reports and oral presentations, as well as to begin thinking about career development skills.
CHEM 50000. Advanced Training for Teachers and Researchers in Chemistry-1. 100 Units.
This course will extend the traditional two-week departmental TA training into a full year, covering both the materials that are critical to becoming an excellent TA and the skills to produce well-rounded PhD candidates. At the end of this course, students are expected to develop an enhanced understanding and talent of critical thinking, an enriched knowledge base that is critical in solving real-world problems, an improved ability in the consideration and use of innovative pedagogical tools, the ability to transition into independent research, and effective skills in preparing high-quality written reports and oral presentations, as well as to begin thinking about career development skills.
Instructor(s): Dr. Vera Dragisich Terms Offered: Autumn

CHEM 50001. Advanced Training for Teachers and Researchers in Chemistry-2. 100 Units.
No description available.
Instructor(s): Dr. Vera Dragisich Terms Offered: Winter

CHEM 50002. Advanced Training for Teachers and Researchers in Chemistry-3. 100 Units.
No description available.
Terms Offered: Spring

CHEM 50001. Advanced Training for Teachers and Researchers in Chemistry-2. 100 Units.
No description available.
Instructor(s): Dr. Vera Dragisich Terms Offered: Winter

CHEM 50002. Advanced Training for Teachers and Researchers in Chemistry-3. 100 Units.
No description available.
Terms Offered: Spring

CHEM 51100. Scientific Methods and Ethics. 100 Units.
This course prepares students for independent research by introducing them to the general methodology of scientific research.
Terms Offered: Not offered in 2015–16