CHEMISTRY*

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Chair: Richard N. Zare
Vice Chair: Wray H. Huestis
Professors: Hans C. Andersen, Steven G. Boxer, John I. Brauman, Hongjie Dai, Michael D. Fayer, Keith O. Hodgson, Wray H. Huestis, Chaitan Khosla, Eric T. Kool, W. E. Moerner, Robert Pecora, Edward I. Solomon, Barry M. Trost, Robert M. Waymouth, Paul A. Wender, Richard N. Zare
Associate Professors: Christopher E. D. Chidsey, Justin Du Bois, Vijay S. Pande, T. Daniel P. Stack
Assistant Professors: Jennifer J. Kohler, Dmitry V. Yandulov
Lecturers: John A. Flygare, Hilary Hua, Christopher R. Moylan
Courtesy Professors: Stacey F. Bent, Curtis W. Frank, Daniel Herschlag
Courtesy Assistant Professors: James K. Chen, Karlene A. Cimprich, Thomas J. Wandless
Director of Undergraduate Laboratories: Christopher R. Moylan

* The curriculum leading to the B.S. degree in Chemical Engineering is described in the "School of Engineering" section of this bulletin.

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Courses given in Chemistry have the subject code CHEM. For a complete list of subject codes, see Appendix.

Chemistry is central to many scientific disciplines and plays an important role in the emerging areas of biotechnology and material science. Fluorescent imaging of biological molecules, modeling of protein folding, manipulation of carbon nanotubes, development of new oxidation and polymerization catalysts, and synthesis of organic molecules for probing ion-channels are all research areas that are pursued actively in the Chemistry department. The overarching theme of these pursuits is a focus at the atomic and molecular levels, whether this concerns probing the reactivity of molecules as small as dihydrogen or synthesizing large polymer assemblies. The ability to synthesize new molecules and materials and to modify existing structures allows the exploration of properties of well-defined systems through systematic modification. The Chemistry department has a long-standing tradition of encouraging undergraduate majors to become involved in research during the academic year and through the 10-week Bing Summer Research Program.

UNDERGRADUATE PROGRAMS

BACHELOR OF SCIENCE

Entrance Preparation—Entrance credit in the preparatory subjects of chemistry, physics, and especially mathematics provides flexibility in creating a four-year schedule for students intending to major in Chemistry.

Minimum Requirements—

Chemistry option: University Writing and General Education Requirements; CHEM 31A and B or 31X, 33, 35, 36, 130, 131, 134, 136, 151, 153, 171, 173, 174, 175, 176; MATH 41, 42, 51, 53, or CME 100, 102, 104; PHYSICS 41, 43, 44, 45, 46.

Biological chemistry option: University Writing and General Education Requirements; CHEM 31A and B or 31X, 33, 35, 36, 130, 131, 134, 136, 151, 171, 173, 176, 184, 185, 188, 189; BIOSCI 41, 42, 44X; MATH 41, 42, 51, 53, or CME 100, 102, 104; PHYSICS 41, 43.

In addition, CS 106A and B are recommended for students planning graduate study. All degree courses must be taken for a letter grade. For further information on the undergraduate program, see http://www.stanford.edu/dept/chemistry/undergrad/.

TYPICAL SCHEDULE FOR A FOUR-YEAR PROGRAM

FIRST YEAR

Subject and Catalog Number	*Qtr. and Units* *A*	*W*	*S*
CHEM 31X. Chemical Principles	4		
CHEM 33. Structure and Reactivity		4	
CHEM 35. Organic Monofunctional Compounds			4
CHEM 36. Organic Chemistry Laboratory I			3
MATH 41, 42, 51. Calculus, Linear Equations	5	5	5

SECOND YEAR

CHEM 130. Organic Chemistry Laboratory II	4		
CHEM 131. Organic Polyfunctional Compounds	3		
CHEM 134. Analytical Chemistry Laboratory			5
CHEM 136. Synthesis Laboratory		3	
MATH 53. Differential Equations			5
PHYSICS 41, 43, 44. Mechanics, Electricity and Magnetism	4	5	

THIRD AND FOURTH YEARS

CHEM 151, 153. Inorganic Chemistry		3	3
CHEM 171, 173, 175. Physical Chemistry	3	3	3
CHEM 174, 176. Physical Chemistry Laboratory		4	3
PHYSICS 45, 46. Light and Heat	5		

* Elective courses must be used to complete the University Writing, General Education, and Language Requirements. They may also be used to broaden one's background in science and nonscience areas and to provide an opportunity for advanced study in Chemistry. Courses offered by other departments that may be of interest to Chemistry majors include BIOSCI 41, 42, 43; CHEMENG 20, 120A,B, 130; CS 106A,B; ECON 1; ENGR 50; MATH 52, 106, 109, 113, 131; MATSCI 50; PHYSICS 110; STATS 60, 110, 116.

MINORS

Courses required for a minor are CHEM 33, 35, 36, 130, 131, 134, 151, 171; MATH 51; and PHYSICS 21, 23, 25, or 28, 29, or 41, 43, 45 (no substitutions). All courses must be taken for a letter grade.

AMERICAN CHEMICAL SOCIETY CERTIFICATION

Students who wish to be certified as having met the minimum requirements of the American Chemical Society for professional training must complete, in addition to the above requirements, CHEM 188 and 189, and 6 units of CHEM 190.

HONORS PROGRAM

A B.S. degree in Chemistry with honors is available to those students interested in chemical research. Admission to the honors program requires a scientific grade point average (GPA) of 3.3 and an overall GPA of 3.0 in all University courses. Beyond the standard B.S. course requirements for each track, 9 units of CHEM 190 research credit, 9 units of course work need to be completed during the junior and senior academic years. For students graduating after 2006-07, a thesis, approved by a Chemistry research adviser, needs to be completed during the senior year. The use of a single course for multiple requirements for honors, major, minor, or coterminal requirements is not allowed. Students who wish to be admitted to the honors program should register in the department student services office in the Mudd Chemistry building.

CHEM 190 research units towards honors may be completed, once accepted into the program, in any laboratory within Chemistry or with courtesy faculty in Chemistry. Other chemical research can be approved through a formal petitioning of the undergraduate studies committee. At least 3 units of CHEM 190 must be completed during the senior year. Participation in a summer research program in an academic setting between junior and senior years may be used in lieu of 3 units of CHEM 190. For each quarter, a progress report reflecting the units undertaken is required. This report must be signed by the Chemistry faculty adviser and filed in the department student services office in Mudd Chemistry before the last day of finals in the quarter during which the research is performed.

The 9 units of course work must be completed from courses approved by the undergraduate studies committee. At least six of these units need to be taken from following CHEM courses: 153, 174, 175, 188, 189, 221, 223, 225, 235, 251, 253, 255, 271, 273, 275, 297. Courses from Mathematics (MATH 114 or higher), Physics (PHYSICS 100 or higher), Engineering, and Structural Biology or Biochemistry in the School of Medicine can be used to fulfill this requirement.

SCHOOL OF HUMANITIES AND SCIENCES

TEACHING CREDENTIALS

The requirements for certification to teach chemistry in the secondary schools of California may be ascertained by consulting the section on credentials under the "School of Education" section of this bulletin and the Credential Administrator of the School of Education.

GRADUATE PROGRAMS

The University's basic requirements for the M.S., M.A.T., and Ph.D. degrees are discussed in the "Graduate Degrees" section of this bulletin.

GENERAL REQUIREMENTS

Placement Examinations—Each new graduate student must take placement examinations on entrance. These consist of three written examinations of two hours each in the fields of inorganic, organic, and physical chemistry, and cover such material as ordinarily is given in a rigorous one-year undergraduate course in each of these subjects. Students majoring in biophysical chemistry or chemical physics must take examinations in biophysical or chemical physics, physical chemistry, and organic or inorganic chemistry. All placement examinations are given the week before instruction begins in Autumn Quarter, and must be taken at that time. Each new graduate student meets with a member of the graduate study committee to define a program of courses based on results of the placement examinations.

Candidates for advanced degrees must have a minimum grade point average (GPA) of 3.0 for all Chemistry lecture courses as well as for all courses taken during graduate study. Required courses must be taken for a letter grade. Most course work ends in the second year of studies and students will then focus on full-time dissertation research. All prospective Ph.D. candidates, regardless of the source of financial support, are required to gain teaching experience as an integral part of graduate training. During the period in which a dissertation is being read by members of the faculty, candidates must be available for personal consultation until the dissertation has had final department approval.

MASTER OF SCIENCE

The Master of Science is available only to current Ph.D. students or as part of a coterm program. Applicants for the M.S. degree in Chemistry are required to complete, in addition to the requirements for the bachelor's degree, a minimum of 45 units of work and a M.S. thesis. Of the 45 units, approximately two-thirds must be in the department and must include at least 12 units of graduate-level lecture courses exclusive of the thesis. Of the 12 units, at least 6 units must be from CHEM 221, 223, 225, 235, 251, 253, 255, 271, 273, 275, 276, or 297.

DOCTOR OF PHILOSOPHY

Graduate students are eligible to become formal candidates for the Ph.D. degree after taking the department placement examinations, satisfactorily completing most of the formal lecture course requirements, and beginning satisfactory progress on a dissertation research project. They then file for admission to candidacy for the Ph.D. degree. This filing must be done before June of the second year of graduate registration.

After taking the departmental placement examinations, students select research advisers by first interviewing members of the Chemistry faculty about their research. Students then file an Application to Start Research form with the Department of Chemistry graduate study committee and begin research on their Ph.D. dissertation under the supervision of the adviser. All students in good standing are required to start research by the end of the Winter Quarter of the first year of graduate registration.

There is no foreign language requirement for the Ph.D. degree.

Candidates for the Ph.D. degree are required to participate continually in the department colloquium (CHEM 300), and in the division seminar of the major subject. In addition, continuous enrollment in CHEM 301 is expected after the student has chosen a research supervisor. As part of graduate training, Ph.D. candidates are required to gain experience as teaching assistants.

Before candidates may request scheduling of the University oral examination, clearance must be obtained from the major professor and the chair of the department's Graduate Study Committee. Conditions that must be fulfilled before clearance is granted vary with the different divisions of the department and may be ascertained by consulting the chair of the committee.

It is the policy of the department to encourage and support in every possible way the pursuit of research and other advanced work by qualified students. Information about faculty members with lists of their recent research publications is found in *Chemistry at Stanford*, the *Directory of Graduate Research* published by the American Chemical Society, and at http://www.stanford.edu/dept/chemistry/faculty.html.

COURSE REQUIREMENTS

Students may major in biophysical, inorganic, organic, or physical chemistry. All graduate students are required to take six graduate-level lecture courses (course numbers greater than 199) of at least 3 units each in chemistry or related disciplines (for example, biochemistry, electrical engineering, mathematics, pharmacology, physics, and so on), to be selected in consultation with their research adviser and the Graduate Study Committee. At least four of these courses should be taken by the end of the first year. Required courses must be taken for a letter grade.

In addition, students majoring in organic chemistry must take 3 units of CHEM 231 in the second year and 3 units of 233 in the second and third year. Students in physical or biophysical chemistry or chemical physics must take CHEM 271, 273, and 275 in the first year, and 2 units of CHEM 278 in the second and third year. Students majoring in inorganic chemistry must take 3 units of CHEM 258 in the second, third, and fourth year.

CHEMICAL PHYSICS

Students with an exceptionally strong background in physics and mathematics may, upon special arrangement, pursue a program of studies in chemical physics.

PH.D. MINOR

Candidates for the Ph.D. degree in other departments who wish to obtain a minor in chemistry must complete, with a GPA of 3.0 or higher, 20 graduate-level units in Chemistry including four lecture courses of at least 3 units each.

FELLOWSHIPS AND SCHOLARSHIPS

In addition to school fellowships and scholarships open to properly qualified students, there are several department fellowships in chemistry. Undergraduate scholarships are administered through the Financial Aid Office. Teaching assistantships and research assistantships are open to graduate students. Graduate fellowships, scholarships, and teaching assistantships are administered through the Department of Chemistry.

COURSES

WIM indicates that the course satisfies the Writing in the Major requirements.

Note—Lab fees are a minimum of $75 per quarter and are not refundable.

UNDERGRADUATE

CHEM 22N. Naturally Dangerous—Stanford Introductory Seminar. Preference to freshmen. Topics from Collman's Naturally Dangerous: Surprising Facts About Food, Health, and the Environment. Designed for nonscientists, but also of interest to scientists and engineers.

2 units, Aut, Spr (Collman, J)

CHEM 24N. Nutrition and History—Stanford Introductory Seminar. Preference to freshmen. Intended to broaden the introductory chemistry experience. The biochemical basis of historically important nutritional deficiencies (vitamins, minerals, starvation, metabolic variants that predispose to disease) and environmental toxins is related to physiological action and the sociological, political, and economic consequences of its effect on human populations. Prerequisite: high school chemistry. Recommended: 31A,B, or 31X, or 33.

2 units, Spr (Huestis, W)

CHEM 25N. Science in the News—Stanford Introductory Seminar. Preference to freshmen. Possible topics include: diseases such as avian flu, HIV, SARS, and malaria; environmental issues such as climate change, and atmospheric pollution, and human population; evolution; stem cell research; nanotechnology; and drug development. The scientific basis for these topics to have an intelligent discussion of societal and political implications. Sources include the popular media and scientific media for the nonspecialist, especially those available on the web.

3 units, Aut (Andersen, H)

CHEM 27N. Lasers: The Light Fantastic—Stanford Introductory Seminar. Preference to freshmen. Introduction to lasers and their impact on everyday life. The operation of lasers using concepts of atomic and molecular energy levels, optics, and resonance. The use of lasers to produce guide stars for astronomy, sculpt the cornea, measure molecules in the ozone layer, transmit optical information over the web, measure the distance to the moon, and observe a single protein molecule in action. Prerequisites: CHEM 31A or X, or PHYSICS 23 and 25, or equivalents. GER: DB-NatSci

3 units, Win (Moerner, W)

CHEM 31A. Chemical Principles I—For students with moderate or no background in chemistry. Stoichiometry; periodicity; simple models of ionic and covalent bonding; dissolution/precipitation, acid/base, and oxidation/reduction reactions; gas laws; phase behavior; rates of reactions. Emphasis is on skills to address structural and quantitative chemical questions; lab provides practice. Recitation. GER: DB-NatSci

4 units, Aut (Chidsey, C)

CHEM 31B. Chemical Principles II—Chemical equilibria; rates and mechanisms to reach equilibrium; thermochemistry, free energy, and relation to equilibrium; quantum concepts, and atomic and molecular orbital theory. Lab provides practice. Recitation. Prerequisite: 31A. GER: DB-NatSci

4 units, Win (Andersen, H)

CHEM 31X. Chemical Principles—Accelerated; for students with substantial chemistry background. Chemical equilibria concepts, equilibrium constants, acids and bases, chemical thermodynamics, quantum concepts, models of ionic and covalent bonding, atomic and molecular orbital theory, periodicity, and bonding properties of matter. Recitation. Prerequisites: high school chemistry and algebra. Recommended: high school physics. GER: DB-NatSci

4 units, Aut (Waymouth, R; Fayer, M), Sum (Staff)

CHEM 33. Structure and Reactivity—Organic chemistry, functional groups, hydrocarbons, stereochemistry, thermochemistry, kinetics, chemical equilibria. Recitation. Prerequisite: 31A,B, or 31X, or an AP Chemistry score of 4 or 5. GER: DB-NatSci

4 units, Win (Stack, T; Kohler, J), Spr (Wender, P), Sum (Staff)

CHEM 35. Organic Monofunctional Compounds—Organic chemistry of oxygen and nitrogen aliphatic compounds. Recitation. Prerequisite: 33. GER: DB-NatSci

4 units, Aut (Huestis, W), Spr (Du Bois, J), Sum (Staff)

CHEM 36. Organic Chemistry Laboratory I—Techniques for separations of compounds; distillation, crystallization, extraction, and chromatographic procedures. Lecture treats theory; lab provides practice. Limited enrollment Spring Quarter; preference to students who have completed CHEM 33. GER: DB-NatSci

3 units, Aut (Moylan, C), Spr (Hua, H), Sum (Moylan, C)

CHEM 110. Directed Instruction/Reading—Undergraduates pursue a reading program under supervision of a faculty member in Chemistry; may also involve participation in lab. Prerequisites: superior work in 31A,B, 31X, or 33; and consent of instructor and the Chemistry undergraduate study committee.

1-2 units, Aut, Win, Spr, Sum (Staff)

CHEM 111. Exploring Chemical Research at Stanford—Preference to freshmen and sophomores. Department faculty describe their cutting-edge research and its applications.

1 unit, Win (Kohler, J)

CHEM 130. Organic Chemistry Laboratory II—Diels-Alder, reduction, and Wittig reactions; qualitative analysis. Lab. Limited enrollment Autumn Quarter. Prerequisite: 36. Corequisite: 35. GER: DB-NatSci

4 units, Aut, Win (Hua, H)

CHEM 131. Organic Polyfunctional Compounds—Aromatic compounds, polysaccharides, amino acids, proteins, natural products, dyes, purines, pyrimidines, nucleic acids, and polymers. Prerequisite: 35. GER: DB-NatSci

3 units, Aut (Kool, E), Win (Trost, B)

CHEM 134. Analytical Chemistry Laboratory—Methods include gravimetric, volumetric, spectrophotometric, and electrometric. Lab. Prerequisite: 130. GER: DB-NatSci, WIM

5 units, Spr (Moylan, C)

CHEM 135. Physical Chemical Principles—Terminal physical chemistry for non-chemistry majors. Emphasis is on portions of physical chemistry most useful for students of the life sciences. Introduction to chemical thermodynamics: rate laws, integration of rate laws, reaction mechanisms, enzyme kinetics, first, second, and third laws, thermochemistry, entropy, free energy, chemical equilibrium, osmotic pressure, other colligative properties. Prerequisites: 31A,B, or 31X, calculus. GER: DB-NatSci

3 units, Win (Pecora, R)

CHEM 136. Synthesis Laboratory—Advanced synthetic methods in organic and inorganic laboratory chemistry. Prerequisites: 35, 130. GER: DB-NatSci

3 units, Win (Yandulov, D)

CHEM 137. Special Topics in Organic Chemistry—(Formerly 181.) Chemical view of the biological processes of life. Topics include: structure and function of proteins, peptides, and nucleic acids; and how to use chemistry to mediate biological processes. GER: DB-NatSci

3 units, Win (Flygare, J)

CHEM 151. Inorganic Chemistry I—Theories of electronic structure, stereochemistry, and symmetry properties of inorganic molecules. Topics: ionic and covalent interactions, electron-deficient bonding, and molecular orbital theories. Emphasis is on the chemistry of the metallic elements. Prerequisites: 35. Recommended: 171. GER: DB-NatSci

3 units, Win (Stack, T)

CHEM 153. Inorganic Chemistry II—The theoretical aspects of inorganic chemistry. Group theory; many-electron atomic theory; molecular orbital theory emphasizing general concepts and group theory; ligand field theory; application of physical methods to predict the geometry, magnetism, and electronic spectra of transition metal complexes. Prerequisites: 151, 173. GER: DB-NatSci

3 units, Spr (Solomon, E)

CHEM 171. Physical Chemistry—Chemical thermodynamics; fundamental principles, Gibbsian equations, systematic deduction of equations, equilibrium conditions, phase rule, gases, solutions. Prerequisites: 31A,B, or 31X, 35; MATH 51. GER: DB-NatSci

3 units, Aut (Pande, V)

CHEM 173. Physical Chemistry—Introduction to quantum chemistry: the basic principles of wave mechanics, the harmonic oscillator, the rigid rotator, infrared and microwave spectroscopy, the hydrogen atom, atomic structure, molecular structure, valence theory. Prerequisites: MATH 51, 53; PHYSICS 51, 53, 55. GER: DB-NatSci

3 units, Win (Boxer, S)

CHEM 174. Physical Chemistry Laboratory I—Experimental investigations in spectroscopy, thermodynamics, and electronics. Students take measurements on molecular systems, design and build scientific instruments, and computer-automate them with software that they write themselves. Prerequisites: 134, PHYSICS 56. Corequisites: 173, MATH 53. GER: DB-NatSci
4 units, Win (Moylan, C)

CHEM 175. Physical Chemistry—Introduction to kinetic theory and statistical mechanics: molecular theory of matter and heat, transport phenomena in gases, Boltzmann distribution law, partition functions for ideal gases. Introduction to chemical kinetics: measurement of rates of reactions, relationship between rate and reaction mechanism, consideration of specific reactions, transition-state theory of reaction rates. Prerequisites: 171, 173. GER: DB-NatSci
3 units, Spr (Moerner, W)

CHEM 176. Physical Chemistry Laboratory II—Use of chemical instrumentation to study physical chemical time-dependent processes. Experiments include reaction kinetics, fluorimetry, and nuclear magnetic and electron spin resonance spectroscopy. Lab. Prerequisites: 173, 174, previous or concurrent enrollment in 175. GER: DB-NatSci
3 units, Spr (Dai, H)

CHEM 184. Biological Chemistry Laboratory—Modern techniques in biological chemistry including protein purification, characterization of enzyme kinetics, heterologous expression of His-tagged fluorescent proteins, site-directed mutagenesis, and single-molecule fluorescence microscopy. Prerequisite: 188.
4 units, Spr (Elrad, D; Kool, E; Zare, R)

CHEM 185. Biochemistry III—Advanced biophysical chemistry. Topics may include spectroscopy and other structure elucidation techniques, photochemistry, advanced quantum mechanics and statistical mechanics, and polymer structure and dynamics, emphasizing biological macromolecules and higher order systems.
3 units, not given this year

CHEM 188. Biochemistry I—(Same as BIOSCI 188/288, CHEMENG 188/288.) Chemistry of major families of biomolecules including proteins, nucleic acids, carbohydrates, lipids, and cofactors. Structural and mechanistic analysis of properties of proteins including molecular recognition, catalysis, signal transduction, membrane transport, and harvesting of energy from light. Molecular evolution. Pre- or corequisites: BIOSCI 41, CHEM 131, and CHEM 135 or CHEM 171. GER: DB-NatSci
3 units, Aut (Kohler, J)

CHEM 189. Biochemistry II—(Same as BIOSCI 189/289, CHEMENG 189/289.) Metabolism. Glycolysis, gluconeogenesis, citric acid cycle, oxidative phosphorylation, pentose phosphate pathway, glycogen metabolism, fatty acid metabolism, protein degradation and amino acid catabolism, protein translation and amino acid biosynthesis, nucleotide biosynthesis, DNA replication, recombination and repair, lipid and steroid biosynthesis. Medical consequences of impaired metabolism. Therapeutic intervention of metabolism. Prerequisite: 188/288. GER: DB-NatSci
3 units, Win (Khosla, C)

GRADUATE

CHEM 221. Advanced Organic Chemistry—Molecular orbital theory and orbital symmetry. Thermochemistry and thermochemical kinetics. Unimolecular reaction rate theory. Methods of determining organic reaction mechanisms from a theoretical and experimental point of view. Prerequisites: 137, 175.
3 units, Aut (Du Bois, J)

CHEM 223. Advanced Organic Chemistry—Continuation of 221 with emphasis on physical methods. Prerequisite: 221 or consent of instructor.
3 units, Win (Trost, B)

CHEM 225. Advanced Organic Chemistry—Continuation of 223. Organic reactions, new synthetic methods, conformational analysis, and exercises in the syntheses of complex molecules. Prerequisite: 223 or consent of instructor.
3 units, Spr (Wender, P)

CHEM 227. Topics in Organic Chemistry—Possible topics: synthetic organic chemistry, photochemistry, inorganic-organic chemistry, bio-organic chemistry, reaction mechanisms, stereochemistry, structural chemistry of organic and biological molecules. May be repeated for credit.
3 units, Aut (Du Bois, J)

CHEM 229. Organic Chemistry Seminar—Required of graduate students majoring in organic chemistry. Students giving seminars register for 231.
1 unit, Aut, Win, Spr (Kohler, J)

CHEM 231. Organic Chemistry Seminar Presentation—Required of graduate students majoring in organic chemistry for the year in which they present their organic seminar. Second-year students must enroll all quarters.
1 unit, Aut, Win, Spr (Waymouth, R)

CHEM 233A,B,C. Creativity in Organic Chemistry—Required of second- and third-year Ph.D. candidates in organic chemistry. The art of formulating, writing, and orally defending a research progress report (A) and two research proposals (B, C). Second-year students register for A and B; third-year students register for C.
1 unit, **A:** *Aut,* **B:** *Spr,* **C:** *Spr (Waymouth, R)*

CHEM 235. Applications of NMR Spectroscopy—The uses of NMR spectroscopy in chemical and biochemical sciences, emphasizing data acquisition for liquid samples and including selection, setup, and processing of standard and advanced experiments.
3 units, Win (Lynch, S)

CHEM 237. Electrochemistry—Principles of electrochemistry and their application to redox systems, electron transfer, electroanalysis, electrodeposition, electrocatalysis, batteries, and fuel cells. Prerequisite: 171 or equivalent.
3 units, Win (Chidsey, C)

CHEM 251. Advanced Inorganic Chemistry—Chemical reactions of inorganic compounds with focus on mechanisms of reactions mediated by inorganic and organometallic complexes. The structural and electronic basis of reactivity including oxidation and reduction; kinetics and thermodynamics of inorganic reactions. Prerequisite: one year of physical chemistry.
3 units, Aut (Yandulov, D)

CHEM 253. Advanced Inorganic Chemistry—Electronic structure and physical properties of transition metal complexes. Ligand field and molecular orbital theories, magnetism and magnetic susceptibility, electron paramagnetic resonance including hyperfine interactions and zero field splitting and electronic absorption spectroscopy including vibrational interactions. Prerequisite: 153 or the equivalent.
3 units, Win (Solomon, E)

CHEM 255. Advanced Inorganic Chemistry—Chemical reactions of organotransition metal complexes and their role in homogeneous catalysis. Analogous patterns among reactions of transition metal complexes in lower oxidation states. Physical methods of structure determination. Prerequisite: one year of physical chemistry.
3 units, Spr (Waymouth, R)

CHEM 258A,B,C. Research Progress in Inorganic Chemistry—Required of all second-, third-, and fourth-year Ph.D. candidates in inorganic chemistry. Students present their research progress in written and oral forms (A); present a seminar in the literature of the field of research (B); and formulate, write, and orally defend a research proposal (C). Second-year students register for A; third-year students register for B; fourth-year students register for C.
1 unit, **A:** *Win,* **B:** *Spr,* **C:** *Aut, Win (Yandulov, D)*

CHEM 259. Inorganic Chemistry Seminar—Required of graduate students majoring in inorganic chemistry.
1 unit, Aut, Win, Spr (Solomon, E)

CHEM 271. Advanced Physical Chemistry—The principles of quantum mechanics. General formulation, mathematical methods, and elementary applications of quantum theory to the structure of atoms and molecules, including variational procedures, perturbation theory, operator and matrix methods, theory of angular momentum, and elements of the electronic structure of atoms. Prerequisite: 175.
3 units, Aut (Fayer, M)

CHEM 273. Advanced Physical Chemistry—Topics in advanced quantum mechanics: vibrations and rotations of polyatomic molecules (normal modes, anharmonicity, wavefunctions and energy levels of rigid rotations, vibration-rotation interaction), ab initio electronic structure theory (Hartree-Fock, configuration interaction, multiconfiguration self-consistent-field, and many-body perturbation theory techniques), angular momentum theory (operators and wavefunctions, Clebsch-Gordan coefficients, rotation matrices), time-dependent quantum mechanics (time evolution operator, Feynman path integrals, scattering theory, Born approximation, Lipmann-Schwinger equation, correlation functions), interaction of radiation and matter (semiclassical and quantum theories of radiation, transition probabilities, selection rules). Prerequisite: 271 or PHYSICS 230.
3 units, not given this year

CHEM 275. Advanced Physical Chemistry—The principles and methods of statistical mechanics from the ensemble point of view, statistical thermodynamics, heat capacities of solids and polyatomic gases, chemical equilibria, equations of state of fluids, and phase transitions. Prerequisite: 271.
3 units, Win (Pande, V)

CHEM 276. Advanced Physical Chemistry—Time-dependent statistical mechanics: ensemble theory for equilibrium and nonequilibrium systems; static and dynamic correlation functions for fluctuating equilibrium systems; the relationship of correlation functions, spectroscopy, and transport; dynamical models used in chemistry, including classical mechanics, quantum mechanics, Brownian dynamics, Smoluchowski dynamics, and Markov processes. Applications to topics in physical chemistry. Prerequisite: 275.
3 units, not given this year

CHEM 277. Topics in Physical Chemistry—Possible topics: structure elucidation using diffraction techniques, advanced statistical mechanics, crystal field theory, advanced quantum mechanics, magnetic relaxation, advanced thermodynamics, chemical applications of group theory. May be repeated for credit. Prerequisite: 275 or consent of instructor.
3 units, Spr (Pecora, R)

CHEM 278A,B. Research Progress in Physical Chemistry—Required of all second- and third-year Ph.D. candidates in physical and biophysical chemistry and chemical physics. Second-year students present their research progress and plans in brief written and oral summaries (A); third-year students prepare a written progress report (B).
1 unit, **A:** *Win,* **B:** *Win (Pecora, R)*

CHEM 279. Physical Chemistry Seminar—Required of graduate students majoring in physical chemistry. May be repeated for credit.
1 unit, Aut, Win, Spr (Dai, H)

CHEM 280. Single-Molecule Spectroscopy and Imaging—Theoretical and experimental techniques necessary to achieve single-molecule sensitivity in laser spectroscopy: interaction of radiation with spectroscopic transitions; systematics of signals, noise, and signal-to-noise; modulation and imaging methods; and analysis of fluctuations; applications to modern problems in biophysics, cellular imaging, physical chemistry, single-photon sources, and materials science. Prerequisites: 271, previous or concurrent enrollment in 273.
3 units, not given this year

CHEM 297. Bio-Inorganic Chemistry—(Same as BIOPHYS 297.) Overview of metal sites in biology. Metalloproteins as elaborated inorganic complexes, their basic coordination chemistry and bonding, unique features of the protein ligand, and the physical methods used to study active sites. Active site structures are correlated with function. Prerequisites: 153 and 173, or equivalents.
3 units, not given this year

CHEM 299. Teaching of Chemistry—Required of all teaching assistants in Chemistry. Techniques of teaching chemistry by means of lectures and labs.
1-3 units, Aut, Win, Spr (Moylan, C)

CHEM 300. Department Colloquium—Required of graduate students. May be repeated for credit.
1 unit, Aut, Win, Spr (Du Bois, J)

CHEM 301. Research in Chemistry—Required of graduate students who have passed the qualifying examination. Open to qualified graduate students with consent of major professor. Research seminars and directed reading deal with newly developing areas in chemistry and experimental techniques. May be repeated for credit.
2 units, Aut, Win, Spr, Sum (Staff)

CHEM 309. Navigating Career Options for Ph.D. Chemists—Planning a post-graduate career. Topics include career options, job search strategies, job application process, long-term career planning, and minority issues in science careers. Workshops focused on developing professional skills working with CDC and CTL, and panel discussions with chemistry Ph.D.s working in a range of fields.
1 unit, Sum (Zare, R)

CHEM 459. Frontiers in Interdisciplinary Biosciences—(Same as BIOC 459, BIOE 459, BIOSCI 459, CHEMENG 459, PSYCH 459.) (Crosslisted in departments in the schools of H&S, Engineering, and Medicine; students register through their affiliated department; otherwise register for CHEMENG 459.) For specialists and non-specialists. Sponsored by the Stanford BioX Program. Three seminars per quarter address scientific and technical themes related to interdisciplinary approaches in bioengineering, medicine, and the chemical, physical, and biological sciences. Leading investigators from Stanford and the world present breakthroughs and endeavors that cut across core disciplines. Pre-seminars introduce basic concepts and background for non-experts. Registered students attend all pre-seminars; others welcome. See http://www.stanford.edu/group/biox/courses/459.html. Recommended: basic mathematics, biology, chemistry, and physics.
1 unit, Aut, Win, Spr (Robertson, C)

RESEARCH AND SPECIAL ADVANCED WORK

CHEM 190. Introduction to Methods of Investigation—Limited to undergraduates admitted under the honors program or by special arrangement with a member of the teaching staff. For general character and scope, see 200. Prerequisite:130. Corequisite: 300.
1-5 units, Aut, Win, Spr, Sum (Staff)

CHEM 200. Research and Special Advanced Work—Qualified graduate students undertake research or advanced lab work not covered by listed courses under the direction of a member of the teaching staff. For research and special work, students register for 200.
1-15 units, Aut, Win, Spr, Sum (Staff)