CHEMISTRY*

Emeriti: (Professors) William A. Bonner, Michel Boudart, Carl Djerassi, Eric Hutchinson, Harden M. McConnell, John Ross, Douglas A. Skoog, Henry Taube, Eugene E. van Tamelen
Chair: Hans C. Andersen
Professors: Hans C. Andersen, Steven G. Boxer, John I. Brauman, James P. Collman, 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, Hongjie Dai, T. Daniel P. Stack
Assistant Professors: Justin Du Bois, Vijay S. Pande, Thomas J. Wandless
Courtesy Professors: Curtis W. Frank, Robert J. Madix
Courtesy Associate Professors: Stacey F. Bent, Daniel Herschlag
Courtesy Assistant Professor: Karlene A. Cimprich
Lecturers: John A. Flygare, Jonathan Touster

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

Department Offices: 121 S. G. Mudd
Mail Code: 94305-5080
Department Phone: (650) 723-2501
Web site: http://www.stanford.edu/dept/chemistry/

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

UNDERGRADUATE PROGRAMS

BACHELOR OF SCIENCE

Entrance Preparation—Students intending to major in chemistry are expected to have entrance credit in the preparatory subjects of chemistry, physics, and mathematics (including algebra and plane trigonometry). Those who do not have entrance credit or equivalent training in these subjects, particularly mathematics, may experience some difficulty in meeting the department requirements for graduation in four years, especially if they expect to pursue a program leading to professional certification by the American Chemical Society or to the B.S. degree with Honors.

Minimum Requirements—University Writing and General Education Requirements; MATH 41, 42, 51, 53; PHYSICS 51, 52, 53, 55, 56; CHEM 31, 33, 35, 36, 131, 132, 133, 134, 151, 153, 171, 173, 174, 175, 176. In addition, CS 106A and 106B are strongly recommended for students planning graduate study. Students interested in attending overseas campuses should consult their advisers as early as possible to avoid scheduling problems. Note that it is particularly convenient to attend an overseas campus during Spring Quarter of the second or third year, since the courses listed in this quarter may be delayed to subsequent years without disadvantage. No required course may be taken on a credit/no credit basis. Information on the undergraduate program is found at http://www.stanford.edu/dept/chemistry/undergraduateweb/.

TYPICAL SCHEDULE FOR A FOUR-YEAR PROGRAM

FIRST YEAR

Course No. and Subject	*Qtr. and Units* A	W	S
CHEM 31. Chemical Principles	4		
CHEM 33. Structure and Reactivity		4	
CHEM 35. Monofunctional Compounds			4
CHEM 36. Chemical Separations			3
MATH 41, 42, 51. Calculus, Linear Equations	5	5	5
Writing and General Education Requirements or Electives*	6	6	3
Totals	15	15	15

SECOND YEAR

CHEM 131. Polyfunctional Compounds	3		
CHEM 132. Qualitative Organic Analysis	5		
CHEM 133. Special Topics in Organic Chemistry		3	
CHEM 134. Theory and Practice of Quantitative Chemistry		5	
CHEM 136. Synthesis Laboratory (elective)			3
MATH 53. Differential Equations			5
PHYSICS 51-52, 53, 55-56. Light and Heat, Mechanics, Electricity, and Magnetism	5	4	5
Electives*		3	7
Totals	18	15	15

THIRD YEAR

CHEM 151, 153. Inorganic Chemistry		3	3
CHEM 171, 173, 175. Physical Chemistry	3	3	3
CHEM 174, 176. Physical Chemistry Laboratory		4	3
Electives*	12	5	6
Totals	15	15	15

FOURTH YEAR

Electives*	15	15	15

* 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 BIOC 200, 241; BIOSCI 41, 42, 43; CHEMENG 20, 120A,B, 130; CS 106A,B; ECON 1; ENGLISH 191; ENGINEER 50; MATH 52, 106, 109, 113, 131, 132; MATSCI 50; PHYSICS 110, 111, 132; STATS 60, 110, 116.

MINORS

Courses required for a minor are CHEM 33, 35, 36, 130 or 132, 131, 134, 151, 171; MATH 51; and PHYSICS 21, 23, 25, or 28, 29, or 51, 53, 55 (no substitutions). No course for the minor may be taken on a credit/no credit basis.

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 136, BIOC 200, 6 units of CHEM 190, and a written report on the CHEM 190 research.

HONORS PROGRAM

A limited number of undergraduates may be admitted to the Chemistry honors program at the beginning of Spring of the junior year. Those completing the program satisfactorily receive the B.S. degree in Chemistry with honors.

Admission to the program requires a grade point average (GPA) of at least 3.0 in all course work in the University. In addition to the minimum requirements for the B.S. degree, the student must complete 9 units of CHEM 190 during the junior/senior years; 9 additional units (including 3 units in Chemistry) from BIOC 200, 237, 241; CHEM 221, 223, 225, 251, 253, 255, 271, 273, 275, 297; MATH 131, 132; MPHA 201; Physics lecture courses numbered greater than 100; or other advanced courses approved by the department's undergraduate study committee; and a written report (two-page minimum) for each quarter of CHEM 190 detailing the progress in the quarter, and reflecting the units undertaken, that is approved by the research adviser, signed by the research adviser, and filed in the department undergraduate office in 283 Mudd before the last day of finals in the quarter during which the research is done. Students may not overlap (double count) courses for completing honors, major, minor, and coterminal requirements. An overall grade point average (GPA) of 3.3 in all Chemistry, Mathematics, and Physics course work including 9 (most recent) units in CHEM 190 is required for a degree with honors.

Students who wish to be admitted to the honors program should register in the department undergraduate office in Mudd 283 at the beginning of Spring Quarter of the junior year. Those who do not meet all of the above formal requirements may petition the department for admission.

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 examinations consist of three written exams 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 must take examinations in biophysical and physical chemistry, and either 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 'B' for all Chemistry lecture courses as well as for all courses taken during graduate study. Required courses may not be taken with the credit/no credit option. All students are expected to give full time to graduate work once they have begun 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

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 an 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 in chemistry exclusive of the thesis. Of the 12 units, at least 6 units must be from CHEM 221, 223, 225, 251, 253, 255, 271, 273, 275, 276, or 297.

MASTER OF ARTS IN TEACHING (CHEMISTRY)

In cooperation with the School of Education, the department offers a program leading to the Master of Arts in Teaching (Chemistry). This degree is for candidates who have a teaching credential and wish to strengthen further their academic preparation. Interested candidates should consult with the chair of the Graduate Study Committee in the Department of Chemistry. Detailed requirements are outlined under the "School of Education, Master of Arts in Teaching" section of this bulletin.

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 at least ten 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 seminar (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 staff 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 the theses 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 in CHEM 231 in the second year and 3 units in 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 in CHEM 278 in the second and third year. Students majoring in inorganic chemistry must take 3 units in 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, against which charges are made for breakage, are a minimum of $35 per quarter. Students taking courses with an * must preregister in the Department of Chemistry.

UNDERGRADUATE

CHEM 22N. Naturally Dangerous—Stanford Introductory Seminar. 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, Spr (Collman)

CHEM 23N. Chemistry and Biology in Biotechnology—Stanford Introductory Seminar. Preference to freshmen. An enrichment of introductory organic chemistry with biological applications. A clinically important molecule is selected to illustrate important contributions that

biology has made to chemistry and vice versa. Topics: structure elucidation of complex molecules, chemical and biological synthesis of complex molecules, mechanism of action, and drug or agrochemical development. Corequisite: 33. GER:2a

3 units, Win (Khosla)

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: 31, 32, or 33.

2 units, Spr (Huestis)

CHEM 25Q. Science-in-Fiction Is Not Science Fiction—Stanford Introductory Dialogue. Preference to sophomores. Science-in-Fiction novels illustrate the practical and ethical problems facing students embarking on a scientific research career. Topics: collegiality and concurrent brutal competition, striving for academic tenure, grantsmanship, and the glass ceiling for women.

2 units, Win (Djerassi)

CHEM 26N. Macromolecules: Is Bigger Better?—Stanford Introductory Seminar. Preference to freshmen. Enrichment of the basic knowledge of chemistry with big molecules. An aspect of macromolecules, or polymers, is that some of their properties depend strongly on local chemical structure. This mix of chemistry and physics is central to understanding the behavior of large molecules. The general features responsible for unusual properties in natural and man-made macromolecules and why polymers are replacing more traditional materials. Prerequisite: high school chemistry. Recommended: 31, 33, or equivalent. GER:2a

3 units, Win (Waymouth) not given 2002-03

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: 31 or PHYSICS 23 or AP Physics. Recommended: PHYSICS 25.

2 units, Win (Moerner)

CHEM 28N. Transforming Chemistry—Stanford Introductory Seminar. Preference to freshmen. Chemistry is "the science that treats of the structure, composition, and properties of substances and of their transformations." Among the four facets identified, transformations is the one that is most particularly the province of the chemist. Topics: transformations, or chemical reactivity in inorganic species, with emphasis on current hot issues. Prerequisite: 31 or 32 or equivalent.

2 units, Spr (Taube)

CHEM 30. Introduction to Chemistry—Preparation for 31. For students with limited background in chemistry and mathematics. Introduction to chemical principles: moles, valence, stoichiometry, definitions, problem solving, quantitative skills. GER:2a

3 units, Aut (Chidsey)

CHEM 31. Chemical Principles—For students with substantial chemistry background. Preparation for chemistry, chemical engineering, medicine, biochemistry, biology, and related fields. Atomic and molecular orbital theory, periodicity, bonding properties of matter, stoichiometry. Recitation. Prerequisites: high school chemistry and algebra. Recommended: high school physics. GER:2a

4 units, Aut (Waymouth, Pecora), Win (Fayer), Sum (Staff)

CHEM 32. The Frontiers of Chemical Science—For students with AP Chemistry scores of 4 or 5 who wish to develop a deeper understanding. Complements a previous rigorous introduction to chemistry, encompassing structure and reactivity, and cutting across the traditional subdivisions of chemistry. Recent advances in structures, analytical methodologies, catalysis, redox phenomena, organometallic, and bio-inorganic chemistry. Lab and recitation. GER:2a

5 units, Aut (Collman, Zare)

CHEM 33. Structure and Reactivity—Organic chemistry, functional groups, hydrocarbons, stereochemistry, thermochemistry, kinetics, chemical equilibria. Recitation. Prerequisite: 31, 32, or an AP Chemistry score of 4 or 5. GER:2a

4 units, Win (Stack, Wandless), Spr (Wender), Sum (Staff)

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

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

CHEM 36. Chemical Separations—Techniques for separations of compounds; distillation, crystallization, extraction, and various chromatographic procedures. Lecture treats the theory; lab provides practice. Prerequisites: 33 and concurrent or previous enrollment in 35.

3 units, Spr (Touster), Sum (Staff)

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 31 or 32, and 33; approval of the instructor and of the Chemistry Undergraduate Study Committee.

1-2 units (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 (Staff)

CHEM 130. Theory and Practice of Identification—(For students in biomedical sciences; Chemistry majors take 132.) Theory and interpretation of ultraviolet, infrared, nuclear magnetic resonance, and mass spectral data. Lab involves identification of unknowns and components of a mixture using derivatives and spectra. Prerequisites: 35, 36 (36 and 130 should be taken in consecutive years). Corequisite: 131.

4 units, Aut (Wandless, Touster)

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

3 units, Aut, Win (Kool, Touster)

CHEM 132. Qualitative Organic Analysis—Required of and limited to chemistry majors; others may be admitted with consent of instructor. Separation of mixtures of organic compounds and identification of the components using rational synthesis and analysis of spectral data. Lab. Prerequisites: 35, 36. Corequisite: 131.

5 units, Aut (Wandless, Touster)

CHEM 133. Special Topics in Organic Chemistry—Primarily for chemistry majors. Organometallic, bioinorganic, and redox chemistry. Prerequisites: 131, calculus.

3 units, Win (Collman)

CHEM 134. Theory and Practice of Quantitative Chemistry—Methods include gravimetric, volumetric, spectrophotometric, and electrometric. Lab. Prerequisite: 130 or 132. (WIM)

5 units, Win (Zare)

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, heterogeneous equilibria, thermodynamics of solutions, electrolytes, chemical kinetics, macromolecular solutions, and colloidal dispersions. Prerequisites: 31, calculus.

3 units, Win (Pecora)

CHEM 136. Synthesis Laboratory—Advanced synthetic methods in organic and inorganic laboratory chemistry. Prerequisites: 130 or 132, 131.

3 units, Spr (Touster)

CHEM 151. Inorganic Chemistry I—Systematic introduction to the theories of electronic structure, stereochemistry, and symmetry properties of inorganic and organometallic molecules. Topics: ionic and covalent interactions, electron-deficient bonding, and elementary ligand field and molecular orbital theories. Emphasis is on the chemistry of the metallic elements. Prerequisites: 35. Recommended: 171.

3 units, Win (Stack)

CHEM 153. Inorganic Chemistry II—Systematic presentation of 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; and theoretical aspects of electron transfer reactions. Prerequisites: 151, 173.

3 units, Spr (Solomon)

CHEM 171. Physical Chemistry—Chemical thermodynamics; fundamental principles, Gibbsian equations, systematic deduction of equations, equilibrium conditions, phase rule, gases, solutions. Prerequisites: 35, MATH 51.

3 units, Aut (Pande)

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.

3 units, Win (Boxer)

CHEM 174. Physical Chemistry Laboratory—Lecture and lab work explore examples from potentiometry, amperometry, and infrared spectroscopy. Instrumental principles include analog and timing electronics, interferometry, computerized data acquisition, and discrete Fourier transform. Physical principles include work, heat, free energy, diffusion, kinetics, and electromagnetic scattering and absorption. Provides a foundation for research with electrochemical and spectroscopic instrumentation and advanced work in laboratory electronics, optics, data processing, and spectroscopy. Prerequisites: 134, 171, previous or concurrent enrollment in 173; MATH 53; and PHYSICS 52, 56.

4 units, Win (Chidsey)

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.

3 units, Spr (Moerner)

CHEM 176. Physical Chemistry Laboratory—Use of chemical instrumentation to study fundamental areas of 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.

3 units, Spr (Dai)

GRADUATE

Undergraduates may register for chemistry courses numbered above 200 only if admitted to the honors program or by consent of the instructor.

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: 133, 175.

3 units, Aut (Kool)

CHEM 223. Advanced Organic Chemistry—Continuation of 221 with emphasis on physical methods. Prerequisite: 221 or consent of instructor.

3 units, Win (Trost)

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)

CHEM 227. Selected 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 (Staff)

CHEM 229. Organic Chemistry Seminar—Attendance required of all graduate students majoring in organic chemistry. Students giving seminars register for 231.

1 unit, Aut, Win, Spr (Staff)

CHEM 231. Organic Chemistry Seminar Presentation—Required of all 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 (Staff)

CHEM 232. Protein Science and Engineering—(Same as CHEMENG 452.) The physio-chemical interactions that govern the structure and function of proteins. Topics: protein function and structure, techniques for probing protein structure and function, mechanisms of protein function, design of proteins with novel properties. Examples from literature on enzymes. Recommended: background in physical and organic chemistry.

3 units, Win (Khosla)

CHEM 233A,B,C. Creativity in Organic Chemistry—Required of all 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) is practiced and criticized. Second-year students register for Autumn (A) and Spring (B), 3rd year students register for Spring (C).

1 unit, **A:** *Aut,* **B:** *Spr,* **C:** *Spr (Staff)*

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)

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 (Solomon) alternate years, given 2003-04

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)

CHEM 257. Research Proposals in Inorganic Chemistry—May be required of second-year students in inorganic chemistry at the discretion of the research adviser. Research progress reports and research proposals are presented in oral and written form. Writing ability, oral defense, and scientific content is criticized..

1 unit, Aut, Win, Spr (Stack)

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). 2nd-year students register for Winter (A), 3rd-year students register for Spring (B), and 4th-year students register for C.

1 unit, **A:** *Win,* **B:** *Spr,* **C:** *Aut, Win, Spr (Staff)*

CHEM 259. Inorganic Chemistry Seminar—Attendance required of all graduate students majoring in inorganic chemistry.

1 unit, Aut, Win, Spr (Stack)

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)

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, Win (Dai)

CHEM 275. Advanced Physical Chemistry—The basic 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, Spr (Pande)

CHEM 277. Selected 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 (Staff)

CHEM 278A,B. Research Progress in Physical Chemistry—Required of all 2nd- and 3rd-year Ph.D. candidates in physical and biophysical chemistry and chemical physics. 2nd-year students present their research progress and plans in brief written and oral summaries (A), 3rd-year students prepare a written progress report (B).

1 unit, **A:** *Win,* **B:** *Win (Staff)*

CHEM 279. Physical Chemistry Seminar—Required of all graduate students majoring in physical chemistry.

1 unit, Aut, Win, Spr (Dai)

CHEM 280. Ultrasensitive Laser Spectroscopy—The theoretical and experimental techniques necessary to achieve extreme sensitivity in laser spectroscopy: interaction of radiation with spectroscopic transitions in chemistry; generation, detection, and modification of laser light; principles of nonlinear optics; applications to modern problems in chemical science such as single-molecule spectroscopy, multiphoton spectroscopy, and gas-phase high resolution spectroscopy of transient species. Prerequisites: 271, previous or concurrent enrollment in 273.

3 units (Moerner) alternate years, given 2003-04

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, Win (Solomon) alternate years, not given 2003-04

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 (Staff)

CHEM 300. Department Colloquium—Required of all graduate students.

1 unit, Aut, Win, Spr (Chidsey)

CHEM 301. Research in Chemistry—Required of all graduate students who have passed the qualifying examination. Open to qualified graduate students with the consent of the major professor. Research seminars and directed reading deal with newly developing areas in chemistry and experimental techniques. May be repeated for credit. Students register giving section number of staff member and number of units agreed upon.

2 units, Aut, Win Spr (Staff)

CHEM 459. Frontiers in Interdisciplinary Biosciences—(Crosslisted in multiple departments in the schools of Humanities and Sciences, Engineering, and Medicine; students should enroll directly through their affiliated department, otherwise enroll in CHEMENG 459.) An introduction to cutting-edge research involving interdisciplinary approaches to bioscience and biotechnology; for specialists and non-specialists. Organized and sponsored by the Stanford BioX Program. Three seminars each quarter address a broad set of scientific and technical themes related to interdisciplinary approaches to important issues in bioengineering, medicine, and the chemical, physical, and biological sciences. Leading investigators from Stanford and throughout the world present the latest breakthroughs and endeavors that cut broadly across many core disciplines. Pre-seminars introduce basic concepts and provide background for non-experts. Registered students attend all pre-seminars in advance of the primary seminars, others welcome. Prerequisite: keen interest in all of science, engineering, and medicine with particular interest in life itself. Recommended: basic knowledge of mathematics, biology, chemistry, and physics.

1 unit, Aut, Win, Spr (Robertson)

RESEARCH AND SPECIAL ADVANCED WORK

190. Introduction to Methods of Investigation—Limited to undergraduate students admitted under the honors program or by special arrangement with a member of the teaching staff. For general character and scope, see 200. Prerequisite: 132. Corequisite: 300.

1-6 units (Staff)

CHEM 200. Research and Special Advanced Work—Qualified graduate students are encouraged to 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 giving section number of staff member under whom work is carried on and number of units agreed upon. Undergraduates, see 190.

1-15 units (Staff)