CHEM 1. Introduction to Organic Chemistry. 4 Units.
First lecture class in summer organic intensive designed for those entering the medical field. Introduction to molecular structure and reactivity of functional groups. Explore chemical reactivity in the context of kinetics and thermodynamics. Prerequisite: College level general chemistry or an AP Chemistry score of 5.

CHEM 10. Exploring Research and Problem Solving Across the Sciences. 2 Units.
Development and practice of critical problem solving and study skills using wide variety of scientific examples that illustrate the broad yet integrated nature of current research. Student teams will have the opportunity to explore and present on topics revolving around five central issues: energy, climate change, water resources, medicine, and food & nutrition from a chemical perspective. Course offered in August prior to start of fall quarter.

CHEM 110. Directed Instruction/Reading. 1-2 Unit.
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.

CHEM 111. Exploring Chemical Research at Stanford. 1 Unit.
Preference to freshmen and sophomores. Department faculty describe their cutting-edge research and its applications.

CHEM 113. Interdisciplinary Approaches to Human Health Research. 1 Unit.
For undergraduate students participating in the Stanford ChEM-H Undergraduate Scholars Program. This course will expose students to interdisciplinary research questions and approaches that span chemistry, engineering, biology, and medicine. Focus is on the development and practice of scientific reading, writing, and presentation skills intended to complement hands-on laboratory research. Students will read scientific articles, write research proposals, make posters, and give presentations. Same as: BIO 193, BIOE 193, CHEMENG 193

CHEM 130. Organic Chemistry Laboratory. 3 Units.
Intermediate organic chemistry laboratory, including synthesis and spectroscopy. Nobel prize winning reactions and characterization techniques, such as Diels-Alder and modified Wittig reactions, as well as IR, NMR, and GCMS; Biodiesel synthesis and lipid characterization. Prerequisite: Chem 35 taken in Aut 2014-15 or later, or Chem 35 and 36. Corequisite: 131.

CHEM 131. Organic Polyfunctional Compounds. 3 Units.
Aromatic compounds, polysaccharides, amino acids, proteins, natural products, dyes, purines, pyrimidines, nucleic acids, and polymers. Prerequisite: 35.

CHEM 132. Synthesis Laboratory. 3 Units.
Focus is on longer syntheses with an emphasis upon using metal catalysts. Emphasis will be on complete characterization of final products using chromatographic and spectroscopic methods. Concludes with an individual synthesis project. Prerequisites: 35, 130.

CHEM 134. Instrumental Analysis Principles and Practice. 5 Units.
The core objectives of the course will focus upon introducing and providing hands-on practice with analytical separation, spectroscopic identification, and calibrated quantification with strong technical communication (for the Writing-in-the-Major requirement) emphasized throughout the course. Lectures will focus upon theory and laboratory activities will provide hands-on practice with the GC, LC, XPS, MS, and UV/Vis instruments. Data analysis will be emphasized throughout the course with MATLAB being the primary tool for plotting and computations. Statistical measurements will be introduced to gauge the quality and validity of data. Lectures will be three times a week with a required four-hour laboratory section. The course will conclude with a student-developed project, focusing upon separation and quantification, and a poster presentation. The course should be completed prior to Chem 174/176/184. Prerequisite: Chem 31B or 31X and concurrent enrollment in Chem 33.

CHEM 137. Design and Synthesis of Polymers. 3 Units.
Polymers are ubiquitous and important for everyday life and advanced technologies for our modern society. Developments in polymer chemistry have allowed the synthesis of polymers with controlled molecular weights, architectures, tacticity, and rich functionalities. Such synthetic controls in macromolecular structures lead to diverse and tunable properties and functions of the produced materials. Therefore, this course also covers basic properties and structure-property relationships of polymers for rational design of structures and selection of chemistry. Polymer chemistry is built on our understanding on the reactivity of organic intermediates, which will be discussed throughout the course. Prerequisite: Organic Chemistry knowledge CHEM 35 and 131.

CHEM 141. The Chemical Principles of Life I. 4 Units.
This is the first course in a two-quarter sequence (Chem 141/143), which will examine biological science through the lens of chemistry. In this sequence students will gain a qualitative and quantitative understanding of the molecular logic of cellular processes, which include expression and transmission of the genetic code, enzyme kinetics, biosynthesis, energy storage and consumption, membrane transport, and signal transduction. Connections to foundational principles of chemistry will be made through structure-function analyses of biological molecules. Integrated lessons in structural, mechanistic, and physical chemistry will underscore how molecular science and molecular innovation have impacted biology and medicine. Prerequisites: CHEM 35, MATH 21 or equivalent.

CHEM 143. The Chemical Principles of Life II. 4 Units.
This is the second course in a two-quarter sequence (Chem 141/143), which will continue the discussion of biological science through the lens of chemistry. In this sequence students will gain a qualitative and quantitative understanding of the molecular logic of cellular processes, which include expression and transmission of the genetic code, enzyme kinetics, biosynthesis, energy storage and consumption, membrane transport, and signal transduction. Connections to foundational principles of chemistry will be made through structure-function analyses of biological molecules. Integrated lessons in structural, mechanistic, and physical chemistry will underscore how molecular science and molecular innovation have impacted biology and medicine. Prerequisite: Chem 141.

CHEM 150. Single-Crystal X-ray Diffraction. 3 Units.
Practical X-ray crystallography for small molecule compounds, which will emphasize crystal growth, measurement strategies, structure solution and refinement, and report generation. Example structures will include absolute configuration of organic compounds (with the heaviest atom being oxygen), metal containing complexes, disordered small molecules and twinning. Students will learn how to get from a new compound to a single crystal, and then to a cif-file ready for publication submission. They will gain knowledge of the underlying theory and concepts for each step of structure determination. Same as: CHEM 250
CHEM 151. Inorganic Chemistry I. 4 Units.
Bonding, stereochemical, and symmetry properties of discrete inorganic molecules are covered along with their mechanisms of ligand and electron exchange. Density function calculations are extensively used in these analyses in computer and problem set exercises. Prerequisites: 35.

CHEM 153. Inorganic Chemistry II. 3 Units.
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.

CHEM 155. Advanced Inorganic Chemistry. 3 Units.
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. Same as: CHEM 255

CHEM 171. Physical Chemistry I. 4 Units.
Laws of thermodynamics, properties of gases, phase transitions and phase equilibrium, chemical equilibrium, chemical kinetics, reaction rate, thermal motion and energy barriers, kinetic molecular models. The MATLAB programming language with hands-on experiences will be introduced in discussion sections and used for simulations of chemical systems. Prerequisites: CHEM 33; PHYS 41; either CME 100 or MATH 51.

CHEM 173. Physical Chemistry II. 3 Units.
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: CHEM 171; CME 102 and CME 104 or MATH 53 or consent from instructor; PHYSICS 41, 43.

CHEM 174. Electrochemical Measurements Lab. 3 Units.
Introduction to modern electrochemical measurement in a hands-on, laboratory setting. Students assemble and use electrochemical cells including indicator, reference, working and counter electrodes, with macro, micro and ultramicro geometries, salt bridges, ion-selective membranes, electrometers, potentiostats, galvanostats, and stationary and rotated disk electrodes. The later portion of the course will involve a student-generated project to experimentally characterize some electrochemical system. Prerequisites: 134, 171, MATH 51, PHYSICS 44 or equivalent. Same as: CHEM 274

CHEM 175. Physical Chemistry III. 3 Units.

CHEM 176. Spectroscopy Laboratory. 3 Units.
Use of spectroscopic instrumentation to obtain familiarity with important types of spectrometers and spectroscopic method and to apply them to study molecular properties and physical chemical time-dependent processes. Spectrometers include electronic ultraviolet/visible absorption, fluorescence, Raman, Fourier transform infrared, and nuclear magnetic resonance. Prerequisite: 173.

CHEM 181. Biochemistry I. 4 Units.
Structure and function of major classes of biomolecules, including proteins, carbohydrates and lipids. Mechanistic analysis of properties of proteins including catalysis, signal transduction and membrane transport. Students will also learn to critically analyze data from the primary biochemical literature. Satisfies Central Menu Area 1 for Bio majors. Prerequisites: CHEM 35 and 135 or 171. Same as: CHEMENG 181, CHEMENG 281

CHEM 183. Biochemistry II. 3 Units.
Focus on metabolic biochemistry: the study of chemical reactions that provide the cell with the energy and raw materials necessary for life. Topics include glycolysis, gluconeogenesis, the citric acid cycle, oxidative phosphorylation, photosynthesis, the pentose phosphate pathway, and the metabolism of glycogen, fatty acids, amino acids, and nucleotides as well as the macromolecular machines that synthesize RNA, DNA, and proteins. Medical relevance is emphasized throughout. Satisfies Central Menu Area 1 for Bio majors. Prerequisite: CHEM 181 or CHEM 143 or CHEMENG 181/281. Same as: CHEMENG 183, CHEMENG 283

CHEM 184. Biological Chemistry Laboratory. 3 Units.
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: 181.

CHEM 185. Biophysical Chemistry. 3 Units.
Primary literature based seminar/discussion course covering classical and contemporary papers in biophysical chemistry. Topics include (among others): protein structure and stability, folding, single molecule fluorescence and force microscopy, simulations, ion channels, GPCRs, and ribosome structure/function. Course is restricted to undergraduates: required for majors on the Biological Chemistry track, but open to students from the regular track. Prerequisites: Chem 171, 173 and 181.

CHEM 187B. Natural Product Biosynthesis: Chemical Logic and Enzymatic Machinery. 1 Unit.
This course provides an overview of the biosynthesis of the five major classes of small molecule natural products, including polyketides, nonribosomal peptides, terpene/isoprenoid scaffolds, alkaloids, and phenylpropanoids. Focus will be on the chemical logic for bond-forming chemical steps in each natural product class and the kinds of enzyme catalysts required to effect complexity-generating molecular scaffolds. This short course runs for the first five weeks of the quarter, from January through the second week of February. Prerequisite: Chem 181 or equivalent. Same as: CHEM 287B

CHEM 190. Advanced Undergraduate Research. 1-5 Unit.
Limited to undergraduates who have completed Chem 35 and/or Chem 134, or by special arrangement with a faculty member. May be repeated 8 times for a max of 27 units. Prerequisite: 35 or 134. Corequisite: 300.

CHEM 196. Creating New Ventures in Engineering and Science-based Industries. 3 Units.
Open to seniors and graduate students interested in the creation of new ventures and entrepreneurship in engineering and science intensive industries such as chemical, energy, materials, bioengineering, environmental, clean-tech, pharmaceuticals, medical, and biotechnology. Exploration of the dynamics, complexity, and challenges that define creating new ventures, particularly in industries that require long development times, large investments, integration across a wide range of technical and non-technical disciplines, and the creation and protection of intellectual property. Covers business basics, opportunity viability, creating start-ups, entrepreneurial leadership, and entrepreneurship as a career. Teaching methods include lectures, case studies, guest speakers, and individual and team projects. Same as: CHEM 296, CHEMENG 296

CHEM 198. Learning Assistant Training Seminar. 1 Unit.
Training seminar for undergraduate students selected for the Learning Assistant (LA) program. This seminar provides LA training and practice in the facilitation of student learning in a collaborative setting, with regular reflection and feedback. In addition, LAs learn mentoring practices to help fellow undergraduates develop academic skills. The seminar meets 90 minutes weekly with additional readings and reflection outside of class. Same as: PHYSICS 198
CHEM 1L. Organic Chemistry Lab 1. 2 Units.
Hands on exploration of laboratory reactions & phenomena discussed in Chem 1. Learn techniques for separation of compounds: distillation, extraction and chromatography (TLC, GCMS) while investigating the nature and properties of organic compounds such as boiling points, polarity, solubility and chirality. Prerequisite: Chem 33 (or course equivalent) or Chem 1 co-requisite.

CHEM 2. Organic Chemistry of Carbonyl Containing Molecules. 4 Units.
Second lecture class in the summer organic intensive series focusing on the synthesis and reactivity of small molecules, with particular emphasis on those that possess the carbonyl functional group. Discuss the importance of the carbonyl functional group to biochemistry. Prerequisite: Chem 33 or Chem 1 or equivalent.

CHEM 200. Research and Special Advanced Work. 1-15 Unit.
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.

CHEM 211A. Research Progress in Chemistry. 1 Unit.
Required of all second year Ph.D. students. Students present their research progress and plans in brief written and oral summaries.

CHEM 211B. Chemistry Research Seminar Presentation. 1 Unit.
Required of all third year Ph.D. students. Students present their research project as a seminar.

CHEM 211C. Chemistry Research Proposal. 1 Unit.
Required of all fourth year Ph.D. students. Students formulate, write, and orally defend an original research proposal.

CHEM 221. Advanced Organic Chemistry I. 3 Units.
Physical organic chemistry: molecular structures, bonding, and non-covalent interactions; thermodynamic and kinetic understanding of reactivity and reaction mechanism. Prerequisite: 175.

CHEM 222. Advanced Organic Chemistry II. 3 Units.
Continuation of 221. Modern synthetic chemistry with an emphasis on selectivity (chemo-, regio-, diastereo-, and enanto-) and atom economy. Prerequisite: 221 or consent of instructor.

CHEM 225. Advanced Organic Chemistry III. 3 Units.
Chemistry is driven by one’s understanding of structure and mechanism and one’s ability to make molecules. This course is intended to address the universal mechanism of organic chemistry with an emphasis on new synthetic methods, selectivity analysis, computer-based strategies for the design and synthesis of complex molecules, concepts for innovative problems solving and, importantly, how to put these skills together in the generation of impactful ideas and proposals directed at solving problems in science as required for a career in molecular science. Prerequisite: 223 or consent of instructor.

CHEM 226. Synthesis and Analysis at the Chemistry-Biology Interface. 3 Units.
Focus on the combined use of organic chemistry and molecular biology to make, manipulate and measure biomacromolecules. Synthetic methods for design and construction of peptides, proteins and nucleic acids; methods for bioconjugation and labeling; fluorescence tools; intracellular delivery strategies; combinatorial selection methods. Prerequisite: One year of undergraduate organic chemistry. Completion of a course in molecular biology is strongly recommended.

CHEM 227. Therapeutic Science at the Chemistry - Biology Interface. 3 Units.
Explores the design and enablement of new medicines that were born from a convergence of concepts and techniques from chemistry and biology. Topics include an overview of the drug development process, design of small molecule medicines with various modes of action, drug metabolism and pharmacogenomics, biologic medicines including protein- and nucleic acid-based therapeutics, glycoscience and glycomimetic drugs, and cell-based medicines derived from synthetic biology. Prerequisite: undergraduate level organic chemistry and biochemistry as well as familiarity with concepts in cell and molecular biology.

CHEM 229. Organic Chemistry Seminar. 1 Unit.
Required of graduate students majoring in organic chemistry. Students giving seminars register for 231.

CHEM 231. Organic Chemistry Seminar Presentation. 1 Unit.
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.

CHEM 233A. Creativity in Organic Chemistry. 1 Unit.
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: A: Aut; B: Spr; C: Spr.

CHEM 233B. Creativity in Organic Chemistry. 1 Unit.
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: A: Aut; B: Spr; C: Spr.

CHEM 233C. Creativity in Organic Chemistry. 1 Unit.
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: A: Aut; B: Spr; C: Spr.

CHEM 235. Applications of NMR Spectroscopy. 3 Units.
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.

CHEM 250. Single-Crystal X-ray Diffraction. 3 Units.
Practical X-ray crystallography for small molecule compounds, which will emphasize crystal growth, measurement strategies, structure solution and refinement, and report generation. Example structures will include absolute configuration of organic compounds (with the heaviest atom being oxygen), metal containing complexes, disordered small molecules and twinning. Students will learn how to get from a new compound to a single crystal, and then to a cif-file ready for publication submission. They will gain knowledge of the underlying theory and concepts for each step of structure determination. Same as: CHEM 150

CHEM 251. Advanced Inorganic Chemistry. 3 Units.
Intended for first-year graduate students and advanced undergraduate students, as a review of how basic concepts in inorganic chemistry can be applied to both molecules and extended solids. Specific topics will include: symmetry, group theory, electronic structure, and reactivity. Prerequisite: Advanced undergraduate-level inorganic chemistry.
CHEM 253. Advanced Inorganic Chemistry. 3 Units.
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.

CHEM 255. Advanced Inorganic Chemistry. 3 Units.
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. Same as: CHEM 155

CHEM 258A. Research Progress in Inorganic Chemistry. 1 Unit.
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.

CHEM 258B. Research Progress in Inorganic Chemistry. 1 Unit.
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.

CHEM 258C. Research Progress in Inorganic Chemistry. 1 Unit.
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.

CHEM 259. Inorganic Chemistry Seminar. 1 Unit.
Required of graduate students majoring in inorganic chemistry.

CHEM 25N. Science in the News. 3 Units.
Preference to freshmen. Possible topics include: diseases such as avian flu, HIV, and malaria; environmental issues such as climate change, atmospheric pollution, and human population; energy sources in the future; evolution; stem cell research; nanotechnology; and drug development. Focus is on the scientific basis for these topics as a basis for intelligent discussion of societal and political implications. Sources include the popular media and scientific media for the nonspecialist, especially those available on the web.

CHEM 261. Computational Chemistry. 3 Units.
Introduction to computational chemistry methods and tools that can be used to interpret and guide experimental research. Project based and hands-on experience with electronic structure calculations, obtaining minimum energy structures and reaction pathways, molecular simulation and modeling. Prerequisite: knowledge of undergraduate level quantum mechanics at the level of Chem 173.

CHEM 26N. The What, Why, How and Wow’s of Nanotechnology. 3 Units.
Preference to freshmen. Introduction to nanotechnology with discussion of basic science at the nanoscale, its difference from molecular and macroscopic scales, and implications and applications. Developments in nanotechnology in the past two decades, from imaging and moving single atoms on surfaces to killing cancer cells with nanoscale tools and gadgets.

CHEM 271. Advanced Physical Chemistry. 3 Units.
The principles of quantum mechanics. General formulation, mathematical methods, and applications of quantum theory. Different representations of quantum theory. i.e., the Dirac, Schrödinger, matrix, and density matrix methods. Time independent exactly solvable problems and approximate methods including time independent perturbation theory and the variational method. Atomic energy calculations, angular momentum, and introduction to molecular structure methods. Time dependent methods. Time dependent perturbation theory applied to various problems such as absorption and emission of radiation. Time dependent density matrix formalism applied to coherent coupling of radiation fields to molecular systems, e.g., NMR and optical spectroscopy. Prerequisite: 175 or equivalent course.

CHEM 273. Advanced Physical Chemistry. 3 Units.
Statistical mechanics is a fundamental bridge that links microscopic world of quantum mechanics to macroscopic thermodynamic properties. We discuss the principles and methods of statistical mechanics from the ensemble point of view. Applications include statistical thermodynamics, quantum systems, heat capacities of gases and solids, chemical equilibrium, pair correlation functions in liquids, and phase transitions. Prerequisite: 271.

CHEM 274. Electrochemical Measurements Lab. 3 Units.
Introduction to modern electrochemical measurement in a hands-on, laboratory setting. Students assemble and use electrochemical cells including indicator, reference, working and counter electrodes, with macro, micro and ultramicro geometries, salt bridges, ion-selective membranes, electrometers, potentiostats, galvanostats, and stationary and rotated disk electrodes. The later portion of the course will involve a student-generated project to experimentally characterize some electrochemical system. Prerequisites: 134, 171, MATH 51, PHYSICS 44 or equivalent.
Same as: CHEM 174

CHEM 275. Advanced Physical Chemistry - Single Molecules and Light. 3 Units.
Covers optical single-molecule detection, spectroscopy, and imaging for detection of motional dynamics, super-resolution structure beyond the diffraction limit, and nanoscale interactions and orientations mostly in biological materials. Recommended: Chem 271 or Phys 230 and Chem 273 or equivalent.

CHEM 277. Materials Chemistry and Physics. 3 Units.
Topics: structures and symmetries and of solid state crystalline materials, chemical applications of group theory in solids, quantum mechanical electronic band structures of solids, phonons in solids, synthesis methods and characterization techniques for solids including nanostructured materials, selected applications of solid state materials and nanostructures. May be repeated for credit.

CHEM 278A. Research Progress in Physical Chemistry. 1 Unit.
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). A: Win, B: Win.

CHEM 278B. Research Progress in Physical Chemistry. 1 Unit.
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). A: Win, B: Win.

CHEM 279. Physical Chemistry Seminar. 1 Unit.
Required of graduate students majoring in physical chemistry. May be repeated for credit.
CHEM 27N. Light and Life. 3 Units.
Preference given to freshman. Light plays a central role in many biological processes and color affects everything in our world. This includes familiar processes such as photosynthesis and vision, but also proton pumps in the organisms that make the Bay purple, green fluorescent protein (GFP), the light from fireflies, the blue and red light receptors responsible for directing how plants grow, the molecules responsible for fall colors, and repair enzymes such as DNA photolysase. Light is also used to interrogate (e.g. super-resolution microscopy) and manipulate (optogenetics) biological systems. Light causes sunburn, but can also be used in combination with special molecules to treat diseases. We will discuss the nature of light, how it is measured, how it is generated in the laboratory, how molecules are excited, and how one measures the fate of this excitation in simple molecules and complex biological systems. Chem 31X or 31A/B preferred, but not required.

CHEM 280. Single-Molecule Spectroscopy and Imaging. 3 Units.
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.

CHEM 285. Biophysical Chemistry. 3 Units.
Primary literature based seminar/discussion course covering classical and contemporary papers in biophysical chemistry. This is intended to provide an introduction to critical analysis of papers in the literature through intensive discussion and evaluation. Topics include (among others): protein structure and stability, folding, single molecule fluorescence and force microscopy, simulations, ion channels, GPCRs, and ribosome structure/function. Course is limited to 15 students and priority will be given to first year Chemistry graduate students.

CHEM 287B. Natural Product Biosynthesis: Chemical Logic and Enzymatic Machinrery. 1 Unit.
This course provides an overview of the biosynthesis of the five major classes of small molecule natural products, including polyketides, nonribosomal peptides, terpene/isoprenoid scaffolds, alkaloids, and phenylpropanoids. Focus will be on the chemical logic for bond-forming chemical steps in each natural product class and the kinds of enzyme catalysts required to effect complexity-generating molecular scaffolds. This short course runs for the first five weeks of the quarter, from January through the second week of February. Prerequisite: Chem 181 or equivalent.

CHEM 28N. Science Innovation and Communication. 3 Units.
Preference to freshmen. The course will explore evolutionary and revolutionary scientific advances; their consequences to society, biotechnology, and the economy; and mechanisms for communicating science to the public. The course will engage academic and industrial thought leaders and provide an opportunity for students to participate in communicating science to the public. This fusion of journalism and science has led to a new undergraduate organization (faScInate), a web site and video presentations. It is an opportunity to share the fun, excitement and importance of science with others.

CHEM 291. Introduction to Nuclear Magnetic Resonance. 3 Units.
Introduction to quantum and classical descriptions of NMR; analysis of pulse sequences and nuclear spin coherences via density matrices and the product operator formalism; NMR spectrometer design; Fourier analysis of time-dependent observable magnetization; NMR relaxation in liquids and solids; NMR strategies for biological problem solving. Prerequisite: Chem 173.

CHEM 296. Creating New Ventures in Engineering and Science-based Industries. 3 Units.
Open to seniors and graduate students interested in the creation of new ventures and entrepreneurial engineering and science intensive industries such as chemical, energy, materials, bioengineering, environmental, clean-tech, pharmaceuticals, medical, and biotechnology. Exploration of the dynamics, complexity, and challenges that define creating new ventures, particularly in industries that require long development times, large investments, integration across a wide range of technical and non-technical disciplines, and the creation and protection of intellectual property. Covers business basics, opportunity viability, creating start-ups, entrepreneurial leadership, and entrepreneurship as a career. Teaching methods include lectures, case studies, guest speakers, and individual and team projects.

CHEM 297. Bio-Inorganic Chemistry. 3 Units.
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 (election transfer; dioxygen binding, activation and reduction to water). Prerequisites: 153 and 173, or equivalents.

CHEM 299. Teaching of Chemistry. 1-3 Unit.
Required of all teaching assistants in Chemistry. Techniques of teaching chemistry by means of lectures and labs.

CHEM 29N. Chemistry in the Kitchen. 3 Units.
This course examines the chemistry relevant to food and drink preparation, both in homes and in restaurants, which makes what we consume more pleasurable. Good cooking is more often considered an art rather than a science, but a small bit of understanding goes a long way to make the preparation and consumption of food and drink more enjoyable. The intention is to have demonstrations and tastings as a part of every class meeting. We will examine some rather familiar items in this course: eggs, dairy products, meats, breads, vegetables, pastries, and carbonated beverages. We shall playfully explore the chemistry that turns food into meals. A high-school chemistry background is assumed; bring to class a good appetite and a healthy curiosity.

CHEM 2L. Organic Chemistry Lab II. 2 Units.
Provides hands on experience with modern chemical methods for preparative and analytical chemistry including GCMS, UV-VIS and IR spectroscopy. Learn how chemoselectivity of reactions can be achieved, synthesize bioactive molecules such as pain relievers, and explore how sunscreens can be made more effective. Prerequisite: Chem 1L. Co-require: Chem 2.

CHEM 3. Organic Chemistry of Biomolecules. 4 Units.
Third lecture class in summer organic intensive focusing on the structure and reactivity of a class of larger molecules, the biomolecules. Topics covered of interest to biochemistry include aromatic compounds, amines and heterocycles, amino acids, proteins, polysaccharides, nucleic acids and polymers. Prerequisite: Chem 35 or Chem 2 or course equivalent.

CHEM 300. Department Colloquium. 1 Unit.
Required of graduate students. May be repeated for credit.

CHEM 301. Research in Chemistry. 2 Units.
Required of 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. Search for adviser name on Axess.

CHEM 31A. Chemical Principles I. 5 Units.
For students with moderate or no background in chemistry. Stoichiometry; periodicity; electronic structure and bonding; gases; enthalpy, phase behavior. Emphasis is on skills to address structural and quantitative chemical questions; lab provides practice. Recitation.
CHEM 31AC. Problem Solving in Science. 1 Unit.
Development and practice of critical problem solving skills using chemical examples. Limited enrollment. Prerequisite: consent of instructor. Corequisite: CHEM 31A.

CHEM 31B. Chemical Principles II. 5 Units.
Chemical equilibrium; acids and bases; oxidation and reduction reactions; chemical thermodynamics; kinetics. Lab. Prerequisite: CHEM 31A.

CHEM 31BC. Problem Solving in Science. 1 Unit.
Development and practice of critical problem solving skills using chemical examples. Limited enrollment and with permission of the instructor. Corequisite: 31B.

CHEM 31X. Chemical Principles Accelerated. 5 Units.
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: AP chemistry score of 5 or passing score on chemistry placement test, and AP Calculus AB score of 4 or Math 20. Recommended: high school physics.

CHEM 33. Structure and Reactivity of Organic Molecules. 5 Units.
Introduction to organic chemistry. Learn to relate three dimensional structure of organic molecules to their chemical and physical properties. Introduced to a variety of functional groups that exhibit patterns of reactivity and learn how to predict products of a reaction in the context of thermodynamics and kinetics. Two hour weekly lab section accompanies the course to introduce the techniques of separation and identification of organic compounds. Prerequisite: 31A,B, or 31X, or AP Chemistry score of 5.

CHEM 33C. Problem Solving in Science. 1 Unit.
Development and practice of critical problem solving skills using chemical examples. Limited enrollment. Prerequisite: consent of instructor. Corequisite: CHEM 33.

CHEM 35. Organic Chemistry of Bioactive Molecules. 5 Units.
Focuses on the structure and reactivity of natural and synthetic bioactive molecules. Covers fundamental concepts underlying chemical reactivity and the logic of chemical synthesis for an appreciation of the profound impact of organic chemistry on humankind in fields ranging from medicine to earth and planetary science. A three hour lab section provides hands on experience with modern chemical methods for preparative and analytical chemistry. Prerequisite: Chem 33.

CHEM 390. Curricular Practical Training for Chemists. 1 Unit.
For Chemistry majors who need work experience as part of their program of study. Confer with Chem student services office for signup.

CHEM 3L. Organic Chemistry Lab III. 2 Units.
Advanced organic lab course that introduces multi-step synthesis, NMR spectroscopy, and polymer chemistry. Learn how to use modern analytical and spectroscopic techniques to determine the structure of organic compounds. Prerequisite: Chem 2L or course equivalent.

CHEM 4. Biochemistry: Chemistry of Life. 4 Units.
A four-week intensive biochemistry course from a chemical perspective. The chemical basis of life, including the biomolecular chemistry of amino acids, proteins, carbohydrates, lipids, and nucleic acids, as well as enzyme kinetics and mechanisms, thermodynamics, and core metabolism, control, and regulation. Recitation includes group work on case studies that support the daily lecture material. Prerequisites: CHEM 33, 35, 131 or 1 year of organic chemistry; Math 19, 20, 21 or 41, 42 or 1 year of single variable calculus.

CHEM 459. Frontiers in Interdisciplinary Biosciences. 1 Unit.
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://biox.stanford.edu/courses/459.html. Recommended: basic mathematics, biology, chemistry, and physics.

Same as: BIO 459, BIOC 459, BIOE 459, CHEMENG 459, PSYCH 459

CHEM 802. TGR Dissertation. 0 Units.

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