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. 1 Unit.
Development and practice of critical problem solving and study skills using a wide variety of scientific examples that illustrate the broad yet integrated nature of current research. Students will build a problem solving tool-kit and apply chemical and mathematical concepts to solve problems related to energy, climate change, water resources, medicine, and food & nutrition. Note: course offered in August prior to start of fall quarter, and only Leland Scholar Program participants will register.

CHEM 100. Chemical Laboratory and Safety Skills. 1 Unit.
This short course is only held in the second week of Autumn quarter. It provides training in basic chemical laboratory procedures and chemical safety to fulfill the safety training requirement for CHEM 121 (formerly CHEM 35) and more advanced laboratory courses. Includes on-line and in-lab training. Successful completion of all course components required for credit. Prerequisite: introductory organic chemistry.

CHEM 121. Organic Chemistry of Bioactive Molecules. 5 Units.
(Formerly CHEM 35) 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 or corequisite CHEM 100.

CHEM 123. Organic Polyfunctional Compounds. 3 Units.
(Formerly CHEM 131.) Analysis of molecular symmetry and spectroscopy, aromaticity, aromatic reactivity, heterocyclic chemistry, chemistry of peptides and DNA. Prerequisite: CHEM 121 (formerly CHEM 35).

CHEM 124. Organic Chemistry Laboratory. 3 Units.
(Formerly Chem 130) Intermediate organic chemistry laboratory with combined synthesis and spectroscopy. Synthesis involves several reactions including Nobel prize winning reactions, such as Diels-Alder and Wittig reactions; characterization techniques include NMR, IR, and GC/MS. Prerequisite: Chem 121 (formerly Chem 35) and corequisite: Chem 123 (formerly 131).

CHEM 126. Synthesis Laboratory. 3 Units.
(Formerly 132) This is a laboratory course that will provide a true experience of what it is like to perform research in synthetic organic chemistry. Emphasis will be on proper reaction setup, reaction monitoring, and complete characterization of final products using chromatographic and spectroscopic methods. Students will be utilizing modern electronic notebooks to prepare for and document their experiments. Concludes with an individual synthesis project. Prerequisites: Chem 124 (formerly Chem 130).

CHEM 129. Design and Synthesis of Polymers. 3 Units.
(Formerly CHEM 137) 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 123 (formerly CHEM 131).

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 on theory, and laboratory activities will provide hands-on practice with the GC, LC, XPS, ICP, 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 courses 174,176, or 184. Prerequisite: CHEM 33 or CHEM 100.

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 121 (formerly 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 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: CHEM 121 (formerly CHEM 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; applications of physical methods to predict the geometry, magnetism, and electronic spectra of transition metal complexes. Prerequisites: CHEM 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 156. Single-Crystal X-ray Diffraction. 3 Units.
(Formerly 150) 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 256

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 MATH 51 or CME 100.

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. Prerequisite: CHEM 171; either MATH 53 or PHYSICS 43; CME 102 and CME 104.

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: CHEM 134 and CHEM 171, MATH 51, PHYSICS 44 or equivalent with corequisite CHEM 100. 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: CHEM 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 121 (formerly 35) and Chem 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 glycerol, 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 a course-based undergraduate research experience (CURE) module. Prerequisite: CHEM 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, Chem 173 and Chem 181.

CHEM 190. Advanced Undergraduate Research. 1-5 Unit.
Limited to undergraduates who have completed Chem 121 (formerly 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: CHEM 121 (formerly 35) or 134. Corequisite: CHEM 300.

CHEM 193. 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 196. Creating and Leading 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: CHEMENG 296, CHEMENG 296

CHEM 1 L. 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.

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 221. Advanced Organic Chemistry I. 3 Units.
This is a course in modern synthetic organic chemistry with an emphasis on structure, reactivity, and stereocontrol. It will draw from underlying physical organic principles in order for students to learn how to analyze complex molecular structures, predict functional group reactivity, propose reasonable reaction mechanisms, and begin to construct multistep syntheses of organic molecules. Syntheses discussed will serve as jumping off points to cover strategy and many types of transformations. A solid foundation in organic chemistry is expected.

CHEM 223. Advanced Organic Chemistry II. 3 Units.
Physical Organic Chemistry. This course is focused on understanding the important physical principles in organic chemistry, including bonding and structural analysis; molecular interactions; thermodynamics; kinetics; methods to investigate reactive intermediates, reactivity, and elucidate reaction mechanism. Prerequisite: Chem 123 (formerly 131).

CHEM 225. Advanced Organic Chemistry III. 3 Units.
Chemistry is driven by one's understanding of structure and mechanism and ones ability to make molecules. This course is intended to address the universal mechanistic and structural foundations 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: CHEM 223 or consent of instructor.

CHEM 229. Design and Synthesis of Polymers. 3 Units.
(Formerly CHEM 137) 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 123 (formerly CHEM 131).
Same as: CHEM 129

CHEM 232. Applications of NMR Spectroscopy. 3 Units.
(Formerly 235) 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 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 251. Advanced Inorganic Chemistry. 3 Units.
(Formerly Chem 253) 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: advanced undergraduate-inorganic course (equivalent to CHEM 153).

CHEM 253. Fundamentals of Inorganic Chemistry. 3 Units.
(Formerly Chem 251) Intended for first-year graduate students and advanced undergraduate students, as a review of how basic concepts in inorganic chemistry can be applied to materials of all dimensionalities. Specific topics will include: symmetry (group theory), bonding models (crystal field theory, valence bond theory, molecular orbital theory, and the Bloch theorem) and electronic structure, and properties/reactivity of molecules and extended solids. Prerequisite: introductory undergraduate-level inorganic course (equivalent to CHEM 151).

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 256. Single-Crystal X-ray Diffraction. 3 Units.
(Formerly 150) 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 ready for publication submission. They will gain knowledge of the underlying theory and concepts for each step of structure determination.
Same as: CHEM 156

CHEM 257. Bio-Inorganic Chemistry. 3 Units.
(Formerly Chem 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 (electron transfer; dioxygen binding, activation and reduction to water). Prerequisites: Chem 153 and Chem 173, or equivalents.
Same as: BIOPHYS 297

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 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: Chem 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: CHEM 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 latter portion of the course will involve a student-generated project to experimentally characterize some electrochemical system. Prerequisites: CHEM 134 and CHEM 171, MATH 51, PHYSICS 44 or equivalent with corequisite CHEM 100. 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. Includes an in-class laboratory component. Recommended: CHEM 271 or PHYSICS 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 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. Chemophysical analyses of costs to lower atmospheric concentrations of greenhouse gases. 3 Units.
Many methods have been proposed to reduce future concentration of CO2, CH4 and other greenhouse gases in the atmosphere from stricter emission regulations, to lower carbon energy sources, to more distribution of existing resources over space and time, to atmospheric capture and sequestration of gases already in the atmosphere. All methods would impose costs in some form. What can chemical and physical analyses tell us about the costs of different approaches? In this graduate-level seminar, students will read primary literature examining the chemical and physical challenges and limitations of various approaches and, by rigorous assessment of the theory and data available to date, will seek to estimate a credible range of future costs for each approach. Prerequisite: Previous study of thermodynamics, kinetics and quantum mechanics at the level of Chemistry 171 and 173.

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: CHEM 271, previous or concurrent enrollment in CHEM 273.

CHEM 281. Therapeutic Science at the Chemistry - Biology Interface. 3 Units.
(Formerly Chem 227) 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 283. Synthesis and Analysis at the Chemistry-Biology Interface. 3 Units.
(Formerly 226) 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 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 28N. SCIENCE COMMUNICATION AND INNOVATION. 3 Units.
Preference to freshmen. From the unique perspective and contributions of students in the class, the course will explore evolutionary and revolutionary scientific advances, including the connections of science to society, art, biotechnology, health care, the environment, energy and the economy as well as strategies for communicating science to the public. The course content will be driven by the interests and passions of the participants who will engage academic and industrial thought leaders, providing an opportunity for students to translate their passion for science, research and journalism into articles, websites, podcasts and videos of interest to others. This fusion of journalism and science has led to a new undergraduate organization (https://fascinatepublication.org), which for some participants would be a venue for continuing involvement in science-journalism. The course is an unique opportunity to create course content, research science of interest and produce publications based on science that excites the participants and to share the fun, excitement and importance of such science to the Stanford and global community.

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 spectrum 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 and Leading 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 196, CHEMENG 196, CHEMENG 296

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 acheived, synthesize bioactive molecules such as pain relievers, and explore how sunscreens can be made more effective. Prerequisite: Chem 1L. Co-requisite: 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.
31A is the first course in a two-quarter sequence designed to provide a robust foundation in key chemical principles for students with limited or no background in chemistry. The course engages students in group problem-solving activities throughout the class periods to deepen their ability to analyze and solve chemical problems. Students will also participate in one weekly laboratory activity that will immediately apply and expand upon classroom content. Labs and write-ups provide practice developing conceptual models that can explain qualitatively and quantitatively a wide range of chemical phenomena. The course will introduce a common language of dimensional analysis, stoichiometry, and molecular naming that enables students to write chemical reactions, quantify reaction yield, and calculate empirical and molecular formulas. Stoichiometry will be immediately reinforced through a specific study of gases and their properties. Students will also build a fundamental understanding of atomic and molecular structure by identifying interactions among nuclei, electrons, atoms and molecules. Through both lab and in-class explanation, students will learn to explain how these interactions determine the structures and properties of pure substances and mixtures using various bonding models including Lewis Dot, VSEPR, and Molecular Orbital Theory. Students will identify and quantify the types and amounts of energy changes that accompany these interactions, phase changes, and chemical reactions, as they prepare to explore chemical dynamics in greater depth in 31B. Special emphasis will be placed on applying content and skills to real world applications such as estimating the carbon efficiency of fossil fuels, understanding hydrogen bonding and other interactions critical to DNA, and calculating the pressure exerted on a deep-sea diver. No prerequisites. Students without AP/IB background are given enrollment priority. This course is not intended for students with AP scores of 4-5; they should instead take Chem 31M. Students with AP 3 or lower should take the chemistry placement exam for further recommendations.

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.
Chem 31B is the second course in this two-quarter sequence, therefore only students who have completed Chem 31A may enroll in 31B. As with 31A, students will continue to engage in group problem-solving activities throughout class and participate in weekly laboratory activities. Labs and write-ups allow students to more deeply explore and observe the different facets of chemical reactivity, including rates (kinetics), energetics (thermodynamics), and reversibility (equilibrium) of reactions. Through experimentation and discussion, students will determine what forces influence the rate of chemical reactions and learn how this can be applied to enzyme reactivity. Students will quantitatively predict chemical concentrations during a reaction, and predict the direction in which a reaction will shift in order to achieve equilibrium, including solubility equilibria. They will use these methods to estimate the possible levels of lead and other toxic metals in drinking water. Special emphasis will be placed on acid/base equilibria, allowing students to explore the role of buffers and antacids in our bodies, as well as ocean acidification and the impact on coral reefs. Students will then bring together concepts from both kinetics and equilibrium, in a deeper discussion of thermodynamics, to understand what ultimately influences the spontaneity of a reaction. Students will build a relationship between free energy, temperature, and equilibrium constants to be able to calculate the free energy of a reaction and understand how processes in our body are coupled to harness excess free energy to do useful work. Finally we will explore how we harness work from redox reactions, building both voltaic cells (i.e., batteries) and electrolytic cells in lab, and using reduction potentials to predict spontaneity and potential of a given reaction. We will look at the applications of redox chemistry in electric and fuel cell vehicles. The course’s particular emphasis on understanding the driving forces of a reaction, especially the influence thermodynamics versus kinetics, will prepare students for further study of predicting organic chemical reactivity and equilibria from structure in Chem 33. 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: CHEM 31B.

CHEM 31M. Chemical Principles: From Molecules to Solids. 5 Units.
A one-quarter course for students who have taken chemistry previously. This course will introduce the basic chemical principles that dictate how and why reactions occur and the structure and properties of important molecules and extended solids that make up our world. As the Central Science, a knowledge of chemistry provides a deep understanding of concepts in fields ranging from materials and environmental science and engineering to pharmacology and metabolism. Discussions of molecular structure will emphasize bonding models including Lewis structures, resonance, valence bond theory, and molecular orbital theory. Lectures will reveal the chemistry of materials of different dimensionality, with emphasis on symmetry, bonding, and electronic structure of molecules and solids. We will also discuss the kinetics and thermodynamics that govern reactivity and dictate solubility and acid-base equilibria. A two-hour weekly laboratory section accompanies the course to introduce laboratory techniques and reiterate lecture concepts through hands-on activities. Specific discussions and laboratories will emphasize the structure, properties, and applications of molecules used in medicine, perovskites and organic dyes used in solar cells, and the dramatically different properties of materials made with only carbon atoms: diamond, graphite, graphene. There will be three lectures, one two-hour laboratory session, an optional 80-minute problem solving session each week. The course will assume familiarity with stoichiometry, unit conversions, and gas laws. Students earning an AP chemistry score of 4 should take CHEM 31M. Students earning an AP score of 5 are welcome to take CHEM 31M, as a refresher, or will receive credit for CHEM 31M. Students who have taken AP chemistry, but scored a 3 or lower, are welcome to take the placement test to place into CHEM 31M. CHEM 31M cannot be used to replace grades earned in CHEM 31X because previously given the placement test to place into CHEM 31M. Students earning an AP score of 5 are welcome to take CHEM 31M, as a refresher, or will receive credit for CHEM 31M. Students who have taken AP chemistry, but scored a 3 or lower, are welcome to take the placement test to place into CHEM 31M. CHEM 31M cannot be used to replace grades earned in CHEM 31X because previously given the courses are not equivalent.

Same as: MATSCI 31

CHEM 329. Organic Chemistry Seminar. 1 Unit.
(Formerly 229) Required of graduate students majoring in organic chemistry. Students giving seminars register for CHEM 231.

CHEM 33. Structure and Reactivity of Organic Molecules. 5 Units.
An introduction to organic chemistry, the molecular foundation to understanding of life, energy, and material science. Students will learn structural and bonding models of organic molecules that provide insights into chemical, physical, and reactivity properties, in addition to their biological activities. Combining these models with kinetic and thermodynamic analyses allows molecular interconversions to be rationalized. Translation of this knowledge to more complex systems empowers the synthesis of novel molecules or materials that can positively impact our society and environment. A two-hour weekly lab section accompanies the course to introduce the techniques of separation and identification of organic compounds. Prerequisite: CHEM 31A and 31B, or CHEM 31M, or CHEM 31X, or AP Chemistry score of 5.

CHEM 33C. Problem Solving in Science. 1 Unit.

CHEM 359. Inorganic Chemistry Seminar. 1 Unit.
(Formerly 259) Required of graduate students majoring in inorganic chemistry.
CHEM 371. Time-dependent statistical mechanics I. 3 Units.
First of a two-quarter sequence on the extension of the principles of statistical thermodynamics to systems away from equilibrium. We will explore the connection between the observable properties of such systems and the properties of their microscopic constituents. It will introduce students to many of the theoretical tools that researchers use to understand different kinds of time-dependent phenomena. The sequence will include coverage of the following topics: Phase space and the Liouville equation; equilibrium time correlation functions (TCFs); simple models of TCFs; linear response theory and transport coefficients; projection operators and generalized equations of motion; functional calculus and the Fokker-Planck, Langevin and generalized Langevin equations; chemical reaction dynamics and the Kramers equation; fluctuation theorems and non-equilibrium work relations; path integrals in the study of stochastic processes. Prerequisites: CHEM 175 or CHEM 273 or equivalent course in equilibrium statistical mechanics.

CHEM 373. Time-dependent statistical mechanics II. 3 Units.
Second of a two-quarter sequence surveying the statistical mechanical principles used in the study of time-dependent phenomena. It will continue to develop the themes introduced in CHEM 371, while illustrating their application to a variety of exactly solvable model systems, with examples drawn from the current research literature. Prerequisite: CHEM 371.

CHEM 379. Physical Chemistry Seminar. 1 Unit.
(Formerly 279) Required of graduate students majoring in physical chemistry. May be repeated for credit.

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, 121, 123 or 1 year of organic chemistry; Math 19, 20, 21 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 90. Directed Instruction/Reading. 1-2 Unit.
(Formerly Chem 110) Undergraduates pursue a reading program under supervision of a faculty member in Chemistry; may also involve participation in lab. Prerequisites: superior work in CHEM 31A, 31B, 31M, 31X, or 33; and consent of instructor.