CHEMISTRY (CHEM)

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.
(Not offered in AY 2020-21) 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 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. Understanding the Natural and Unnatural World through Chemistry. 5 Units.
Students enrolled in this course will appreciate the transformative power of molecular science on the modern world and how foundational knowledge of chemistry enables profound discoveries in biological, pharmaceutical, agrochemical, engineering, energy, and materials science research. This course integrates the lessons of CHEM 31 and CHEM 33 through an examination of the structure-function properties of carbon-based molecules. Specific emphasis is given to the chemistry of carbonyl- and amine-derived compounds, polyfunctionalized molecules, reaction kinetics and thermodynamics, mechanistic arrow-pushing, and retrosynthetic analysis. Students will be empowered with a conceptual understanding of chemical reactivity, physical organic chemistry, and the logic of chemical synthesis. The singular nature of molecular design and synthesis to make available functional molecules and materials will be revealed. A three-hour lab section provides hands on experience with modern chemical methods for preparative and analytical chemistry. Prerequisite CHEM 33 or co-requisite CHEM 100 (not required in AY 2020-21).

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

CHEM 124. Organic Chemistry Laboratory. 3 Units.
This is a laboratory course that serves as a stepping stone toward independent research in organic chemistry. Through several 1-2 step syntheses, this course trains students on basic organic laboratory techniques on purification of products, including extraction, distillation, recrystallization, thin layer chromatography, and column chromatography, as well as characterization of product structures using IR, GC-MS, and NMR spectroscopy. This course reviews MS, IR, and 1H and 13C NMR spectroscopy knowledge from Chem 33 and 121 with an emphasis on the practical interpretation of spectra, so that students can become independent in using these techniques to identify the purity and structures of organic compounds.nPrerequisite: Chem 121. Corequisite: Chem 123.

CHEM 126. Synthesis Laboratory. 3 Units.
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.

CHEM 131. 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 Python 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, MATH 21 or equivalent.

CHEM 143. The Chemical Principles of Life II. 4 Units.
(Not offered in AY2020-21) 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 33.

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: 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. Foundations of Physical Chemistry. 4 Units.
Quantum and statistical thermodynamics: obtaining quantum mechanical energy levels and connecting them to thermodynamic properties using statistical mechanics. Emphasis will be on quantum mechanics of ideal systems (e.g. particle in a box, particle in a ring, harmonic oscillator, hydrogen atom) and their connection to and uses in thermodynamics (laws of thermodynamics, properties of gases, chemical equilibria, thermal motion and energy barriers, and rates of chemical reactions). Homeworks and discussion sections will employ the Python programming language for hands-on experience with simulating chemical systems. Prerequisites: CHEM 33; PHYS 41; CS106A; 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. Prerequisites: 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 131 (formerly 134) and CHEM 171, MATH 51, PHYSICS 44 or equivalent.
Same as: CHEM 274

CHEM 175. Physical Chemistry III. 3 Units.
Molecular theory of kinetics and statistical mechanics: transport and reactions in gases and liquids, ensembles and the Boltzmann distribution law, partition functions, molecular simulation, structure and dynamics of liquids. Diffusion and activation limited reactions, potential energy surfaces, collision theory and transition-state theory. Prerequisites: CHEM 171, CHEM 173.

CHEM 176. Spectroscopy Laboratory. 3 Units.
Use of spectroscopic instrumentation to obtain familiarity with important types of spectrometers and spectroscopic methods and to apply them to study molecular properties and time dependent processes. Methods include electronic ultraviolet/ visible absorption, fast fluorescence with time correlated single photon counting, Raman and fluorescence microscopy, Fourier transform infrared absorption, 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).
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 141 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: CHEM 296, CHEMENG 196, CHEMENG 296

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 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. 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 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 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 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 undergrad-level 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-file 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 (election transfer; dioxygen binding, activation and reduction to water). Prerequisites: Chem 153 and Chem 173, or equivalents.
Same as: BIOPHYS 297

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 methodology with a focus on interpretation of and applications to experimental research. Project-based and hands-on experience with molecular dynamics simulation, determining reaction pathways, Monte Carlo simulation and modeling, and machine learning for applications in chemistry. Prerequisite: knowledge of undergraduate level quantum mechanics and statistical mechanics at the levels of Chem 173 and Chem 175.

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 later portion of the course will involve a student-generated project to experimentally characterize some electrochemical system. Prerequisites: CHEM 131 (formerly 134) and CHEM 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. May include an in-class laboratory component. Recommended: CHEM 271 or PHYSICS 230 and CHEM 273 or equivalent.

CHEM 277. Materials Chemistry and Physics. 3 Units.
(Not offered in AY2020-21) 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 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 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, with special focus on DNA and RNA. Synthetic and enzymatic methods for design and construction of oligonucleotides and nucleic acids; methods for bioconjugation and labeling; fluorescence tools; intracellular delivery strategies; selection and evolution methods; CRISPR mechanisms. 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 289. Concepts and Applications in Chemical Biology. 3 Units.
Current topics include chemical genetics, activity-based probes, inducible protein degradation, DNA/RNA chemistry and molecular evolution, protein labeling, carbohydrate engineering, fluorescent proteins and sensors, optochemical/optogenetic methods, mass spectrometry, and genome-editing technologies.

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 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 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 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 weekly labs that will apply and expand upon class content. Due to social distancing guidelines, labs will be held over live Zoom. Students can opt-in to receive an at home lab kit that will allow them to conduct low-risk portions of the labs from their location. TAs will demonstrate and guide students through hands-on portions, as well as supplement with further in-depth video labs, virtual simulations, and problem solving practice. n31A will provide practice developing conceptual models that can explain qualitatively and quantitatively a wide range of chemical phenomena and will be immediately applied to real world challenges. Students practice dimensional analysis, stoichiometry, and molecular naming that enables them to write chemical reactions, quantify reaction yield, and calculate empirical and molecular formulas. Using these skills, students estimate carbon efficiency of fossil fuels and identify unknowns in forensic analysis. Stoichiometry is reinforced through study of gases and their properties, through which students calculate the pressure exerted on a deep-sea diver. Students examine atomic and molecular structure by quantifying interactions among nuclei, electrons, atoms and molecules and explain trends in reactivity, such as why potassium metal catches fire in water. They explore how these interactions determine the structures and properties of pure substances, mixtures, proteins, and even DNA using three conceptual models for bonding: Lewis Dot, VSEPR, and Molecular Orbital Theory. They investigate the types and amounts of energy changes that accompany these interactions, phase changes, and chemical reactions, such as measuring the caloric content of food and dissecting an instant hand warmer. By the end of the course, students will be prepared to explore chemical reactivity in greater depth in 31B. nAll students who are interested in taking general chemistry at Stanford must take the Autumn 2020 General Chemistry Placement Test before Autumn quarter begins, regardless of chemistry background. Students with no AP/IB background are given enrollment priority in the 31A/B sequence.

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 will 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 quantify 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 of 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 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, environmental science, and engineering to pharmacology and metabolism. Discussions of molecular structure will describe bonding models including Lewis structures, resonance, crystal-field theory, and molecular-orbital theory. We 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 will include the structure, properties, and applications of molecules used in medicine, perovskites used in solar cells, and the dramatically different properties of materials with the same composition (for example: diamond, graphite, graphene). There will be three lectures, one two-hour laboratory session, and an optional 80-minute problem solving session each week. The course will assume familiarity with stoichiometry, unit conversions, and gas laws. All students who are interested in taking general chemistry at Stanford must take the Autumn 2020 General Chemistry Placement Test before Autumn quarter begins, regardless of chemistry background. Generally students earning an AP chemistry score of 4 or higher place into 31M. Students earning an AP score of 5 are also welcome to take the Autumn 2020 Chemistry 33 Placement Test to see if Chem33 is a more appropriate placement. Same as: MATSCI 31.
Same as: MATSCI 31

CHEM 321. Topics in Stereochemistry. 3 Units.
Most areas of modern organic chemistry require of an understanding of stereochemical concepts. This course will discuss relevant developments in three central fields of stereochemistry, (1) conformational analysis, with particular emphasis in the influence of stereoelectronic interactions, (2) asymmetric synthesis, with specific applications in the stereoselective synthesis of a- and b-amino acids, and (3) sustainable chemistry and asymmetric organocatalysis. A solid foundation in organic chemistry is expected.

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, medicine, imaging, 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, collectively contributing to the molecularization and thus advancement of many science disciplines. Combining these models with kinetic and thermodynamic analyses allows molecular conversions to be rationalized. Translation of this knowledge to more complex systems enables the synthesis of novel molecules or materials that can positively impact our science, 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 31B or CHEM 31M.

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 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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CHEM 90. 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 CHEM 31A, 31B, 31M, 31X, or 33; and consent of instructor.

CHEM 91. Exploring Chemical Research at Stanford. 1 Unit.
Preference to freshmen and sophomores. Department faculty describe their cutting-edge research and its applications.