CHEMISTRY (CHEM)

CHEM 104a, Chemistry of Food and Cooking  Staff
Fundamental principles for understanding chemical structures and interactions as well as energy and speed of chemical processes. Application of these principles to food and cooking, including demonstrations. This course is designed for non-STEM majors. Prerequisite: preference given to students who have not taken AP or college-level chemistry.  SC  o Course cr

CHEM 134La or b, General Chemistry Laboratory I  Staff
An introduction to basic chemistry laboratory methods. Techniques required for quantitative analysis of thermodynamic processes and the properties of gases. To accompany or follow CHEM 161 or 163. May not be taken after a higher-numbered laboratory course.  SC  RP  o Course cr

CHEM 136La or b, General Chemistry Laboratory II  Staff
Introduction to rate and equilibrium measurements, acid-base chemistry, synthesis of inorganic compounds, and qualitative/quantitative analysis. After CHEM 134L or the equivalent in advanced placement. To accompany or follow CHEM 165 or 167. May not be taken after a higher-numbered laboratory course.  SC  RP  o Course cr

* CHEM 163a, Advanced General Chemistry I  Staff
An in-depth examination of the principles of atomic, molecular, and solid state chemistry, including structures, periodicity, and chemical reactivity. Topics include the quantum mechanics of atoms and chemical bonding, and inorganic, organic, and solid state molecules and materials. For students with strong secondary school exposure to general chemistry. Attendance at a weekly discussion section required. Normally accompanied by CHEM 134L. Enrollment by placement only.  QR, SC  RP  o Course cr

* CHEM 165a or b, General Chemistry II  Staff
Topics include kinetics, chemical equilibrium, acid-base chemistry, free energy and entropy, electrochemistry, and nuclear chemistry. Attendance at a weekly discussion section required. Prerequisite: CHEM 161. Normally accompanied by CHEM 136L. Enrollment by placement only.  QR, SC  RP  o Course cr

* CHEM 167b, Advanced General Chemistry II  Hailiang Wang
Topics include kinetics, chemical equilibrium, acid-base chemistry, free energy and entropy, electrochemistry, and nuclear chemistry. Attendance at a weekly discussion section required. Prerequisite: CHEM 163, or with equivalent placement. Normally accompanied by CHEM 156L. Enrollment by placement only.  QR, SC  RP

* CHEM 174a, Organic Chemistry for First Year Students I  Staff
An introductory course focused on current theories of structure and mechanism in organic chemistry, their development, and their basis in experimental observation. Open to freshmen with excellent preparation in chemistry, mathematics, and physics who have taken the department's advanced chemistry placement examination. Attendance at a weekly discussion section required. Normally accompanied by CHEM 222L. Enrollment by placement only.  SC  RP  o Course cr

* CHEM 174b, Organic Chemistry for First Year Students II  David Spiegel
Continuation of CHEM 174. Survey of simple and complex reaction mechanisms, spectroscopy, organic synthesis, and the molecules of nature. Attendance at a weekly discussion section required. After CHEM 174. Normally accompanied by CHEM 223L. Enrollment by placement only.  SC  RP  o Course cr

CHEM 220a or b, Organic Chemistry  Staff
An introductory course covering the fundamental principles of organic chemistry. The laboratory for this course is CHEM 222L. After college-level general chemistry. Students who have earned a grade lower than C in general chemistry are cautioned that they may not be sufficiently prepared for this course. Usually followed by CHEM 221 or 230.  SC  RP  o Course cr

CHEM 221b, The Organic Chemistry of Life Processes  Scott Miller
The principles of organic reactivity and how they form the basis for biological processes. The laboratory for this course is CHEM 223L. After CHEM 220. Students who have earned a grade lower than C in CHEM 220 are cautioned that they may not be sufficiently prepared for this course.  SC  RP

CHEM 222La or b, Laboratory for Organic Chemistry I  Staff
First term of an introductory laboratory sequence covering basic synthetic and analytic techniques in organic chemistry. Prerequisite: CHEM 156L or equivalent. After or concurrently with CHEM 174 or 220.  SC  o Course cr

CHEM 223Lb, Laboratory for Organic Chemistry II  Christine DiMeglio
Second term of an introductory laboratory sequence covering basic synthetic and analytic techniques in organic chemistry. Prerequisite: CHEM 222L. After or concurrently with CHEM 175, 221, or 230.  SC ½ Course cr

CHEM 226La, Intensive Advanced Chemistry Laboratory  Christine DiMeglio
An intensive course in advanced chemistry laboratory technique intended to bring the student closer to independent research. Included are an independent laboratory project and presentation, introduction to library research, and training in the use of various analytical techniques. Offered subject to available laboratory space and sufficient enrollment. After CHEM 223L. Enrollment is limited; e-mail course instructor for enrollment procedure.  WR, SC  RP
* **CHEM 230a, Organic Chemistry of Biological Pathways**  Staff
Chemical principles that underpin living systems explored through organic chemistry. Examples drawn from chemistry, medicine, biotechnology, and the emergent field of chemical biology. Key conceptual frameworks such as structure, function, and mechanism and their relations to the chemistry of proteins, nucleic acids, selected drugs, and other topics in the life sciences. Mechanistic principles are used to examine enzymatic processes and the role of cofactors in the context of primary metabolism and natural products biosynthesis. After CHEM 220. Students must sign up for discussion sections using the Preference Selection tool.  SC  ½ Course cr

**CHEM 251Lb, Inorganic Chemistry Laboratory**  Jonathan Parr
Introductory laboratory course covering synthetic and physical characterization techniques in inorganic chemistry. Prerequisite: CHEM 119L or 222L; concurrently with or after CHEM 252.  SC

**CHEM 252b, Introductory Inorganic Chemistry**  Patrick Holland
Principles and applications of modern inorganic chemistry. Introduction to some of the fundamental concepts of solid-state chemistry, coordination chemistry, bioinorganic chemistry, and organometallic chemistry. Prerequisite: college-level general chemistry. After or concurrently with CHEM 220 or by permission of instructor. May not be taken after CHEM 450, 452, or 457.  SC  RP

**CHEM 328a, Physical Chemistry with Applications in the Biological Sciences**  Staff
Physical chemical principles and their application to the chemical and life sciences. Thermodynamics, chemical and biochemical kinetics, solution physical chemistry, electrochemistry, and membrane equilibria. CHEM 332 is preferred for Chemistry majors. Prerequisites: introductory physics, college-level general chemistry, and single-variable calculus, or permission of instructor; MATH 120 or ENAS 151 suggested. May not be taken after CHEM 332.  QR, SC  RP  0 Course cr

**CHEM 330La or b, Laboratory for Physical Chemistry I**  Staff
Introduction to the tools and techniques of modern experimental physical chemistry, including analog/digital electronics, quantitative measurements of basic thermodynamic properties, and nuclear magnetic resonance spectrometry. After or concurrently with CHEM 328 or 332.  SC  RP  0 Course cr

**CHEM 331Lb, Laboratory for Physical Chemistry II**  Paul Cooper
Application of physical methods to chemical analysis by spectroscopic and spectrometric techniques. Please see the course syllabus for details regarding course registration. After CHEM 330L. After or concurrently with CHEM 333.  SC  RP

* **CHEM 332a, Physical Chemistry with Applications in the Physical Sciences I**  Staff
A comprehensive survey of modern physical and theoretical chemistry, including topics drawn from thermodynamics, chemical equilibrium, electrochemistry, and kinetics. Prerequisites: introductory physics, college-level general chemistry, and single-variable calculus, or permission of instructor; MATH 120 or ENAS 151 suggested. May not be taken after CHEM 332.  QR, SC  RP  0 Course cr

* **CHEM 333b, Physical Chemistry with Applications in the Physical Sciences II**  Patrick Vaccaro
Continuation of CHEM 332, including topics drawn from quantum mechanics, atomic/molecular structure, spectroscopy, and statistical thermodynamics. Prerequisite: CHEM 328 or 332, or permission of instructor. Recommended preparation: familiarity with differential equations.  QR, SC  RP

**CHEM 355Lb, Chemical Biology and Bioanalytical Chemistry Laboratory**  Stacy Malaker
The goal of the Chemical Biology and Bioanalytical Chemistry Laboratory is to involve students in the challenge and excitement of instrumentation analysis, before such research opportunities might normally be available. Students work in teams and are assigned an unknown protein. They express, purify, and characterize their assigned protein via affinity chromatography, NMR, X-ray scattering, and mass spectrometry. This course is heavily reliant on the Chemical and Biophysical Instrumentation Center (CBIC), where students get hands-on experience with instruments. The semester culminates with students writing a manuscript in JACS format, followed by a conference-style poster session. Prerequisite: General chemistry lab, organic chemistry lab, one semester of biochemistry or chemical biology, or permission of instructor.  SC

* **CHEM 400a, Current Chemistry Seminar**  Narasimhan Ganapathi and Jonathan Parr
Designed to engage students in the Chemistry research-seminar program by providing requisite scientific guidance and a forum for directed discussion. Participants explore current avenues of chemical research as presented orally by the prime movers in the field, thereby exploring the frontiers of current knowledge while still retaining the structured environment of a classroom. May fulfill all or part of the senior requirement for the Chemistry major, as detailed in the program description in the YCPS.

**CHEM 402a, Fundamentals of Transition Metal Chemistry**  Patrick Holland
This half-term course covers the structures and properties of coordination compounds, and strategies for the design and analysis of new compounds. Elements of chelating ligands, spectroscopic methods, and magnetism are addressed. Prerequisites: Two terms of organic chemistry, and Chem 252 or equivalent.  SC  ½ Course cr

**CHEM 403a, Fundamentals of Organometallic Chemistry**  Nilay Hazari
A half-term survey of the main principles of organometallic chemistry that enable students to understand basic concepts in the field. It prepares students for CHEM 404, Applications of Organometallic Chemistry, the second half of this course. Prerequisites: Two terms of organic chemistry and Chem 252 or equivalent experience.  SC  ½ Course cr
CHEM 404a, Applications of Organometallic Chemistry  
Nilay Hazari
A half-term survey of the applications of organometallic chemistry that demonstrates to students the range of areas where organometallic reactions are important. It builds on the knowledge learned in CHEM 403, Fundamentals of Organometallic Chemistry. Prerequisites: Two terms of organic chemistry, one of CHEM 252, and CHEM 403 or equivalent experience.  
SC ½ Course cr

CHEM 405b, Inorganic Reaction Mechanisms  
James Mayer
This half-term course covers the fundamentals of kinetics and mechanisms used by coordination compounds and transition-metal catalysts, and features analysis of papers from the recent literature. Prerequisites: Two terms of organic chemistry, Chem 252 or equivalent, and CHEM 402 or equivalent.  
SC ½ Course cr

CHEM 406a, Bioinorganic Spectroscopy  
Gary Budvig
This course is an advanced introduction to biological inorganic chemistry with an emphasis on the methods used to characterize the active sites of metalloproteins. The major physical methods used in the determination of molecular structure, bonding and physical properties of metal ions in proteins are introduced. Prerequisite: A general knowledge of biochemistry and familiarity with both inorganic coordination chemistry and physical chemistry.  
SC ½ Course cr

CHEM 408a, Principles of Materials Chemistry  
Hailiang Wang
This course is an advanced introduction to materials chemistry. It aims to serve senior undergraduate students who are interested in learning and applying chemical principles for materials research and applications. Fundamental principles in solid-state chemistry, including crystal structures and chemical interactions, will be taught. Ionics, metal, semiconductor and polymer materials, including their synthesis, structures, properties and applications, will be discussed. Prerequisite: General chemistry, inorganic chemistry and physical chemistry, or equivalent experience.  
SC ½ Course cr

CHEM 416a, Organic Structure and Energetics  
William Jorgensen
The course covers concepts in physical organic chemistry including molecular structure & bonding, conformational energetics, electronic effects, thermochemistry, ring strain, non-covalent interactions, molecular recognition, and host-guest chemistry. Prerequisites: Two terms of organic chemistry and two terms of physical chemistry or related courses or permission of the instructor.  
SC ½ Course cr

CHEM 417a, Kinetics and Thermodynamics in Organic Systems  
Scott Miller
The course generally follows Organic Structure and Energetics. This module covers concepts in physical organic chemistry including acid-base chemistry, advanced issues in stereochemistry, kinetics and thermodynamics, as well as experiments and techniques employed in mechanistic analysis. Issues in catalysis are addressed throughout. Prerequisites: CHEM 416 and two terms of introductory organic chemistry, and two terms of physical chemistry. Permission of the instructor may be sought for potential exceptions.  
SC ½ Course cr

CHEM 419a, Foundations of Chemical Biology  
Stacy Malaker
Chemical biology is a rapidly developing field at the interface of chemical and biological sciences. This subject deals with how chemistry can be applied to manipulate and study biological problems using a combination of experimental techniques ranging from organic chemistry, analytical chemistry, biochemistry, molecular biology, biophysical chemistry and cell biology. The purpose of this course is to teach students the core skills that are used by scientists at the interface of chemistry and biology. The course transitions into Chemical Biology II, where students learn more about therapeutic applications of chemical biology. Prerequisites: Two terms of both general chemistry and organic chemistry.  
SC ½ Course cr

CHEM 424a, Applications of Chemical Biology to Therapy  
David Spiegel
This course explores the design and enablement of medicines derived from a convergence of concepts and techniques from chemistry and biology. Topics include: small molecule drug discovery concepts and tools, drug metabolism, protein therapeutics, hybrid chemical/biologic drugs, and bifunctional molecules. Modern approaches for target discovery and validation are also discussed. Prerequisites: CHEM 419, two semesters of undergraduate organic chemistry, or permission of instructor. A basic understanding of biochemistry and molecular biology is assumed.  
SC ½ Course cr

CHEM 425b, Spectroscopic Methods of Structure Determination  
Martin Saunders
Applications of NMR, ESR, infrared, UV, visible, and mass spectroscopy to chemical problems concerning structures and reactions. X-ray crystallography. Computer simulation of NMR spectra. Prerequisites: two terms of organic chemistry and CHEM 333.  
SC RP

CHEM 432a, Synthetic Methods in Organic Chemistry I  
Jon Ellman
Compound synthesis is essential to the discovery and development of new chemical entities with a desired property whether that be for fundamental study or for a more applied goal such as a new pharmaceutical, agrochemical, or material. In this course we emphasize key transformations and principles to provide a framework for the efficient design and synthesis of organic compounds. Prerequisites: Two terms of organic chemistry and one term of introductory inorganic chemistry, or related course, or permission of the instructor.  
SC ½ Course cr

CHEM 432a, Synthetic Methods in Organic Chemistry II  
Jon Ellman
Compound synthesis is essential to the discovery and development of new chemical entities with a desired property whether that be for fundamental study or for a more applied goal such as a new pharmaceutical, agrochemical, or material. In this course we emphasize key transformations and principles to provide a framework for the efficient design and synthesis of organic compounds. This course builds on the knowledge learned in CHEM 432. Prerequisite: CHEM 432 or permission of instructor.  
SC ½ Course cr
CHEM 437a, Chemistry of Isotopes  Martin Saunders
Advanced applications of isotopes to chemical problems and the theory associated with them, including kinetic and equilibrium isotope effects, tracer applications, and dating.  RP

CHEM 466a, Introduction to Quantum Mechanics 1  Sharon Hammes-Schiffer
A half-term introduction to quantum mechanics, starting with the Schrödinger equation and covering model systems such as particle-in-a-box and harmonic oscillator. The fundamental postulates and theorems of quantum mechanics are also covered. Prerequisite: Physical chemistry, multivariable calculus or equivalent experience.  SC ½ Course cr

CHEM 467a, Introduction to Quantum Mechanics 2  Sharon Hammes-Schiffer
Continuation of an introduction to quantum mechanics, starting with angular momentum and the hydrogen atom, and then covering approximate methods such as the variation method and perturbation theory. The concepts of electron spin as well as Hartree-Fock theory and other electronic structure methods for describing molecules are covered. Half-term course. Prerequisite: CHEM 467, or multivariable calculus or equivalent experience.  SC ½ Course cr

* CHEM 472a, Introduction to Statistical Mechanics 1  Victor Batista
A half-term introduction to modern statistical mechanics, starting with fundamental concepts on quantum statistical mechanics to establish a microscopic derivation of statistical thermodynamics. Topics include ensembles, Fermi, Bose and Boltzmann statistics, density matrices, mean field theories, phase transitions, chemical reaction dynamics, time-correlation functions, Monte Carlo simulations and Molecular Dynamics simulations. Prerequisites: Physical chemistry, multivariable calculus or equivalent experience.  SC ½ Course cr

* CHEM 473a, Introduction to Statistical Mechanics 2  Victor Batista
A half-term continuation of the introduction to modern statistical mechanics, with focus on quantum statistical mechanics of liquids, Monte Carlo methods and linear response theory (Chapters 6-8 of the textbook). Classical results are obtained according to the classical limit of the quantum mechanical description. Topics include the Monte Carlo simulations and Molecular Dynamics simulations for the description of the Ising model, fluids, solvation of solutes, alchemist free energy calculations, kinetics and transport properties. Prerequisites: Physical chemistry, multivariable calculus or equivalent experience.  SC ½ Course cr

* CHEM 480a or b, Introduction to Independent Research in Chemistry  Nilay Hazari
After consultation with the DUS, students engage individual experimental and/or theoretical research problems in the laboratories of a selected faculty member within the Chemistry department. At the end of the term, students submit a brief report summarizing goals, methods, and accomplishments. For each term of enrollment, students must complete the CHEM 480 registration form, available in the DUS office, and have it signed by their faculty research mentor. It must be submitted to the Chemistry DUS for final approval no later than the last week of classes in the immediately preceding academic term. Individuals wishing to perform independent research must have demonstrated proficiency in the aspects of chemistry required for the planned project, as ascertained by the supervising faculty member, and must meet basic safety requirements prior to undertaking any activities, including certified completion of the online courses entitled Laboratory Chemical Training and Hazardous Chemical Waste Training administered by the Office of Environmental Health and Safety (EHS) at http://ehs.yale.edu/training. At least ten hours per week of research are required (including time spent on requisite safety training), with the faculty mentor affirming this level of student commitment by midterm. This course may be taken multiple times for Pass/Fail credit, subject to restrictions imposed by Yale College.  RP

* CHEM 490a or b, Independent Research in Chemistry  Staff
Senior Chemistry majors engage individual experimental and/or theoretical research problems in the laboratories of a selected faculty member in the Chemistry department or in a closely related field of molecular science. CHEM 490 registration forms, found in the DUS office, must be signed by the student’s faculty research mentor and submitted it to the Chemistry DUS for final approval no later than the last week of classes in the immediately preceding academic term. Mandatory class meetings address issues of essential laboratory safety and ethics in science, with other class sessions focusing on core topics of broad interest to Chemistry students, including online literary research, oral presentation skills, and effective scientific writing. At least ten hours of research are required per week. Students are assigned letter grades, subject to restrictions imposed by Yale College. In special cases and with DUS approval, juniors may take this course.  RP

CHEM 492a, Biochemical Rates and Mechanisms 1  J Patrick Loria
An advanced treatment of enzymology. Topics include transition state theory and derivation of steady-state and pre-steady-state rate equations. The role of entropy and enthalpy in accelerating chemical reactions is considered, along with modern methods for the study of enzyme chemistry. These topics are supplemented with in-depth analysis of the primary literature Prerequisites: CHEM 332 or equivalent, two semesters of organic chemistry, Math 115.  SC ½ Course cr

CHEM 496a, Computational Chemistry  Sharon Hammes-Schiffer
An introduction to modern computational quantum chemistry methods. The lectures cover Hartree-Fock theory, density functional theory, geometry optimizations, thermochemistry, transition states, minimum energy paths, continuum solvation models, electron correlation methods, and modeling excited states. Special emphasis on the hands-on use of computational packages for current applications spanning organic, inorganic, and biochemical reactions. After physical chemistry or with permission of instructor.  QR, SC ½ Course cr