CHEMISTRY (CHEM)

CHEM 101a, Chemistry in the Modern World  N. Ganapathi
Basic concepts necessary to understand how chemistry affects life in the modern world. Laws, events, and other ways that chemistry shapes human lives. Intended for non-science majors; no prerequisites. Does not satisfy premedical chemistry requirements or requirements for the Chemistry major. Not open to students who have completed another chemistry course at Yale.  SC

CHEM 106b, Chemistry and Forensics  N. Ganapathi
Chemistry principles, including but not limited to, atoms, molecules, molecular structure and properties, solutions, fire, explosions, radioactivity, drugs and poisons, and DNA analysis, as applied to forensic analysis. No prerequisites; intended for non-science majors. Does not satisfy premedical chemistry requirements or requirements for the Chemistry major. Not open to students who have completed another chemistry course at Yale.  SC

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 161a or b, General Chemistry I  Staff
A comprehensive survey of modern descriptive, inorganic, and physical chemistry. Atomic theory, stoichiometry, thermochemistry, chemical periodicity, concepts in chemical bonding, and the shapes of molecules. Appropriate either as a first chemistry course or for students with one year of high school chemistry. Attendance at a weekly discussion section required. Normally accompanied by CHEM 134L. QR, 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  
Mark Johnson
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 136L. Enrollment by placement only. QR, SC RP 0 Course cr

* 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 0 Course cr

* CHEM 175b, Organic Chemistry for First Year Students II  
Scott Miller
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 0 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 0 Course cr

CHEM 221b, The Organic Chemistry of Life Processes  
Jason Crawford
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 0 Course cr

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 136L or equivalent. After or concurrently with CHEM 174 or 220. SC 0 Course cr

CHEM 223Lb, Laboratory for Organic Chemistry II  
Staff
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 0 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 251Lb, Inorganic Chemistry Laboratory  Jonathan Parr
Introductory laboratory course covering synthetic and physical characterization techniques in inorganic chemistry. Prerequisite: 222L; concurrently with or after CHEM 252. SC 0 Course cr

CHEM 252b, Introductory Inorganic Chemistry  Hailiang Wang
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 0 Course cr

CHEM 330La, 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 0 Course cr

* 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 328. 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 0 Course cr

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  Jonathan Parr and Christine DiMeglio
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**  Patrick Holland
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 404b, 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 406b, Bioinorganic Spectroscopy**  Gary Brudvig
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 407b, Bioinorganic Mechanisms**  Gary Brudvig
This course is an advanced introduction to biological inorganic chemistry. An overview of the relevant geometric and electronic structures of metalloprotein active sites are presented and related to each protein's function. The objective is to define and understand the function of metals in biology in terms of structure. Prerequisite: CHEM 406 or permission of instructor. It will be assumed that students have a general knowledge of biochemistry and are familiar with both inorganic coordination chemistry and physical chemistry.  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.  \( \text{SC} \) 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.  \( \text{SC} \) 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.  \( \text{SC} \) ½ Course cr

**CHEM 420a, Foundations of Chemical Biology II: Protein Design & Catalysis**  Jason Crawford

The lecture component of this course largely focuses on protein function and catalysis of diverse small molecule natural products. The course also serves to teach students how to write an effective NSF style research proposal in Chemical Biology and communicate its contents to a diverse scientific audience. Prerequisite: CHEM 419 or permission of instructor. Note that the prerequisite for CHEM 419 is two semesters of undergraduate organic chemistry. A basic understanding of biochemistry and molecular biology is assumed, but students can “catch up” by carefully and thoroughly reading the course materials and recommended books.  \( \text{SC} \) ½ Course cr

**CHEM 424a, Foundations of Chemical Biology II: Applications of Chemical Biology to Therapeutics**  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.  \( \text{SC} \) ½ Course cr

**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 433a, 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 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, or permission of instructor. 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  Nilay Hazari and Jonathan Parr
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 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 492b, Biochemical Rates and Mechanisms I  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 496b, 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