Chemistry and Chemical Biology (CHEM)

CHEM 1000. Chemistry/Chemical Biology at Northeastern. 1 Hour.
Intended for freshmen in the College of Science. Introduces students to liberal arts; familiarizes them with their major; develops the academic skills necessary to succeed (analytical ability and critical thinking); provides grounding in the culture and values of the University community; and helps to develop interpersonal skills—in short, familiarizes students with all skills needed to become a successful university student.

CHEM 1101. General Chemistry for Health Sciences. 4 Hours.
Provides a one-semester introduction to general chemistry for the health sciences. Covers the fundamentals of elements and atoms; ionic and molecular structure; chemical reactions and their stoichiometry, energetics, rates, and equilibriums; and the properties of matter as gases, liquids, solids, and solutions. Other topics include acids and bases, and nuclear chemistry. Applications to the health sciences are included throughout.

CHEM 1102. Lab for CHEM 1101. 1 Hour.
Accompanies CHEM 1101. Covers a range of topics from the course, such as qualitative and quantitative analysis and the characteristics of chemical and physical processes. Includes measurements of heat transfer, rate and equilibrium constants, and the effects of temperature and catalysts. Emphasis is on aqueous acid-base reactions and the properties and uses of buffer systems.

CHEM 1103. Recitation for CHEM 1101. 0 Hours.
Accompanies CHEM 1101. Covers various topics from the course.

CHEM 1104. Organic Chemistry for Health Sciences. 4 Hours.
Provides a one-semester introduction to organic chemistry for the health sciences. Covers the fundamentals of the structure, nomenclature, properties, and reactions of the compounds of carbon. Also introduces biological chemistry including amino acids, proteins, carbohydrates, lipids, nucleic acids, hormones, neurotransmitters, and drugs. Applications to the health sciences are included throughout.

CHEM 1105. Lab for CHEM 1104. 1 Hour.
Accompanies CHEM 1104. Covers a range of topics from the course, such as the properties and elementary reactions of hydrocarbons, alcohols, ethers, carbonyl compounds, carbohydrates, and amines.

CHEM 1106. Recitation for CHEM 1104. 0 Hours.
Accompanies CHEM 1104. Covers various topics from the course.

CHEM 1107. Introduction to Forensic Science. 4 Hours.
Introduces students to the field of forensic science from both a scientific and a legal perspective. Examines the challenges and methodologies of crime scene investigation, forensic biology, and forensic chemistry. Provides real-world case studies and examines some misrepresentations of forensics by television dramas. Emphasizes scientific evidence associated with topics such as DNA analysis, drug abuse, and explosion investigations, as well as other relevant topics.

CHEM 1109. The Chemistry of Food and Cooking. 4 Hours.
Introduces a number of basic scientific principles in the methodology of cooking, food preparation, and the enjoyment of food. Focuses on the chemistry and molecular bases of food, reactivity under various conditions, molecular gastronomy, geographic and cultural influences on food, and food as preventative medicine. Class demonstrations of various cooking techniques illustrate different chemical principles between food and cooking. Designed for students who do not plan to major in the natural sciences.

CHEM 1117. Chemical Perspectives on Energy. 4 Hours.
Examines the chemical principles that underly the major sources of energy for society, including combustion of fossil fuels, biofuels, batteries, solar energy, and nuclear power. Examines the costs and benefits to society of each energy source. Does not substitute for CHEM 1101, CHEM 1151, or CHEM 1211. High school chemistry strongly recommended.

CHEM 1118. Recitation for CHEM 1117. 0 Hours.
Offers a small-group recitation setting for discussion of homework problems and completing group exercises in CHEM 1117.

CHEM 1151. General Chemistry for Engineers. 4 Hours.
Corresponds to one semester of study in important areas of modern chemistry, such as details of the gaseous, liquid, and solid states of matter; intra- and intermolecular forces; and phase diagrams. Presents the energetics and spontaneity of chemical reactions in the context of chemical thermodynamics, while their extent and speed is discussed through topics in chemical equilibria and kinetics. Aspects of electrochemical energy storage and work are considered in relation to batteries, fuel, and electrolytic cells.

CHEM 1152. Lab for CHEM 1151. 1 Hour.
Accompanies CHEM 1151. Complements and reinforces the material in CHEM 1151 with emphasis on examples of interest in the context of modern materials, energy storage, and conversion.

CHEM 1153. Recitation for CHEM 1151. 0 Hours.
Accompanies CHEM 1151. Offers a weekly sixty-five-minute drill/discussion session conducted by chemistry faculty or graduate teaching assistants. Discusses the homework assignments of CHEM 1151 in detail with emphasis on student participation.

CHEM 1161. General Chemistry for the Biological Sciences. 4 Hours.
Introduces the principles of chemistry, focusing on the particulate nature of matter and its interactions and reactions that form the basis for the underlying molecular dynamics of living systems. Presents basic concepts of chemical bonding and intermolecular interactions for molecules and molecules' behavior in aqueous solutions with examples from biologically relevant molecules. Introduces kinetics and chemical thermodynamics with examples from biological systems. Offers students an opportunity to obtain a framework for understanding the chemical basis for different methods for separating and purifying biological compounds.

CHEM 1162. Lab for CHEM 1161. 1 Hour.
Accompanies CHEM 1161. Introduces basic laboratory techniques. Covers a range of topics including qualitative and quantitative analysis and the characteristics of chemical and physical processes.

CHEM 1163. Recitation for CHEM 1161. 0 Hours.
Accompanies CHEM 1161. Covers various topics from the course. Offers students an opportunity to work interactively with instructors and other students to learn and apply the knowledge acquired in lecture.

CHEM 1211. General Chemistry 1. 4 Hours.
Introduces the principles of chemistry, focusing on the states and structure of matter and chemical stoichiometry. Presents basic concepts and definitions, moles, gas laws, atomic structure, periodic properties and chemical bonding, all within a contextual framework.

CHEM 1212. Lab for CHEM 1211. 1 Hour.
Accompanies CHEM 1211. Covers a range of topics from the course including qualitative and quantitative analysis and the characteristics of chemical and physical processes.

CHEM 1213. Recitation for CHEM 1211. 0 Hours.
Accompanies CHEM 1211. Covers various topics from the course.

CHEM 1214. General Chemistry 2. 4 Hours.
Continues CHEM 1211. Introduces the principles of chemical equilibrium, the rates and mechanisms of chemical reactions, and energy considerations in chemical transformations. Covers solutions, chemical kinetics, chemical equilibria, chemical thermodynamics, electrochemistry, and chemistry of the representative elements. Such contextual themes as energy resources, smog formation, and acid rain illustrate the principles discussed.

CHEM 1215. Lab for CHEM 1214. 1 Hour.
Accompanies CHEM 1214. Covers a range of topics from the course, such as measurements of heat transfer, rate and equilibrium constants, and the effects of temperature and catalysts. Particular attention is paid to aqueous acid-base reactions and to the properties and uses of buffer systems. Quantitative analysis of chemical and physical systems is emphasized throughout.

CHEM 1216. Recitation for CHEM 1214. 0 Hours.
Accompanies CHEM 1214. Covers various topics from the course.

CHEM 1217. General Chemistry 1 for Chemical Science Majors. 4 Hours.
Offers the first of a two-semester sequence (with CHEM 1220) that introduces students majoring or intending to major in chemistry to the principles of chemistry with an emphasis on relating the macroscale physical and chemical properties of substances to the structure and behavior of the particles (atomic particles, ions, and molecules) of which they are composed. Explores the connections between chemistry and the other sciences, particularly the life and environmental sciences. Topics include atomic and molecular structure, bonding theories, intermolecular interactions, reactions in the gas phase and in aqueous solutions, the energetics of chemical change, and the properties of gases and solutions.

CHEM 1218. Lab for CHEM 1217. 2 Hours.
Accompanies CHEM 1217. Explores nuclear chemistry, atomic structure, chemical reactions in the gas phase and in solutions, chemical bonding, intermolecular forces, and the properties of gases. The results of experiments form the basis for problem-solving sessions in CHEM 1217.

CHEM 1219. Recitation for CHEM 1217. 0 Hours.
Accompanies CHEM 1217. Provides students with opportunities to work interactively with instructors and other students to learn and apply the scientific method.

CHEM 1220. General Chemistry 2 for Chemical Science Majors. 4 Hours.
Continues CHEM 1217. Offers the second of a two-semester sequence (following CHEM 1217) of guided inquiries into the principles of chemistry including the structure of solids, thermochemistry, thermodynamics, chemical kinetics, chemical equilibrium, acids and bases, and electrochemistry and materials chemistry.

CHEM 1221. Lab for CHEM 1220. 2 Hours.
Accompanies CHEM 1220. Explores the structure of solids, thermochemistry, thermodynamics, chemical kinetics, chemical equilibrium, acids and bases, and electrochemistry and materials chemistry. The results of experiments form the basis for problem-solving sessions in CHEM 1220.

CHEM 1222. Recitation for CHEM 1220. 0 Hours.
Accompanies CHEM 1220. Provides students with opportunities to work interactively with instructors and other students to learn and apply the understandings acquired in lab and lecture.

CHEM 1990. Elective. 1-4 Hours.
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

CHEM 2311. Organic Chemistry 1. 4 Hours.
Introduces nomenclature, preparation, properties, stereochemistry, and reactions of common organic compounds. Presents correlations between the structure of organic compounds and their physical and chemical properties, and mechanistic interpretation of organic reactions. Includes chemistry of hydrocarbons and their functional derivatives.

CHEM 2312. Lab for CHEM 2311. 1 Hour.
Accompanies CHEM 2311. Introduces basic laboratory techniques, such as distillation, crystallization, extraction, chromatography, characterization by physical methods, and measurement of optical rotation. These techniques serve as the foundation for the synthesis, purification, and characterization of products from microscale syntheses integrated with CHEM 2311.

CHEM 2313. Organic Chemistry 2. 4 Hours.
Continues CHEM 2311. Focuses on additional functional group chemistry including alcohols, ethers, carbonyl compounds, and amines, and also examines chemistry relevant to molecules of nature. Introduces spectroscopic methods for structural identification.

CHEM 2314. Lab for CHEM 2313. 1 Hour.
Accompanies CHEM 2313. Basic laboratory techniques from CHEM 2312 are applied to chemical reactions of alcohols, ethers, carbonyl compounds, carbohydrates, and amines. Introduces basic laboratory techniques including infrared (IR) spectroscopy and nuclear magnetic resonance (NMR) spectronomy as analytical methods for characterization of organic molecules.

CHEM 2315. Organic Chemistry 1 for Chemistry Majors. 4 Hours.
Reviews the basics of bonding and thermodynamics of organic compounds as well as conformational and stereochemical considerations. Presents the structure, nomenclature, and reactivity of hydrocarbons and their functional derivatives. Highlights key reaction mechanisms, providing an introduction to the methodology of organic synthesis.

CHEM 2316. Lab for CHEM 2315. 2 Hours.
Accompanies CHEM 2315. Introduces basic laboratory techniques, such as distillation, crystallization, extraction, chromatography, characterization by physical methods, and measurement of optical rotation. These techniques serve as the foundation for the synthesis, purification, and characterization of products from microscale syntheses integrated with CHEM 2315.

CHEM 2317. Organic Chemistry 2 for Chemistry Majors. 4 Hours.
Continues CHEM 2315. Extends the study of functional groups commonly found in organic compounds, further emphasizing conceptual mastery of the relationship between structure and reactivity. Introduces structural identification of organic compounds using contemporary spectroscopic methods such as IR, MS, and NMR. Other topics include structure and reactivity of conjugated and aromatic systems, the chemistry of ethers and epoxides, and the chemistry of carbonyl-containing compounds including aldehydes, ketones, carboxylic acids, and carboxylic acid derivatives. Offers students an opportunity to develop skills in planning multistep syntheses using the retrosynthesis approach and proposing mechanisms for chemical transformations.

CHEM 2318. Lab for CHEM 2317. 2 Hours.
Accompanies CHEM 2317. Introduces basic laboratory techniques including infrared (IR) spectroscopy and nuclear magnetic resonance (NMR) spectronomy as analytical methods for characterization of organic molecules. These methods serve as the basis for characterization of products from microscale syntheses.

CHEM 2319. Recitation for CHEM 2311. 0 Hours.
Offers students opportunities to work interactively with instructors and other students to learn and apply the understandings acquired in lab and lecture.

CHEM 2320. Recitation for CHEM 2313. 0 Hours.
Offers students opportunities to work interactively with instructors and other students to learn and apply the understandings acquired in lab and lecture.

CHEM 2324. Recitation for CHEM 2315. 0 Hours.
Accompanies CHEM 2315 and CHEM 2316. Offers students an opportunity to work interactively with instructors and other students to learn and apply the knowledge acquired in lab and lecture.

CHEM 2325. Recitation for CHEM 2317. 0 Hours.
Accompanies CHEM 2317 and CHEM 2318. Offers students an opportunity to work interactively with instructors and other students to learn and apply the knowledge acquired in lab and lecture.

CHEM 2331. Bioanalytical Chemistry. 4 Hours.
Develops good critical thinking and problem-solving skills through the exploration of open-ended group projects in a laboratory-based course centered on the analytical chemistry of biomolecules. Develops an understanding of the practice and business aspects of analytical chemistry as they relate to research and development labs in the biotechnology/pharmaceutical industry.

CHEM 2332. Lab for CHEM 2331. 1 Hour.
Accompanies CHEM 2331. Working in teams, students investigate real- world, open-ended research problems in the field of bioanalytical chemistry, broadly defined using modern analytical instrumentation.

CHEM 2990. Elective. 1-4 Hours.
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

CHEM 3403. Quantum Chemistry and Spectroscopy. 4 Hours.
Studies the theory of quantum chemistry with applications to spectroscopy. Presents some simple quantum mechanical (QM) models, including the particle in a box, rigid rotor, and harmonic oscillator, followed by treatments of electrons in atoms and molecules. Microwave, infrared, Raman, NMR, ESR, atomic absorption, atomic emission, and UV-Vis spectroscopy are discussed in detail.

CHEM 3404. Lab for CHEM 3403. 1 Hour.
Accompanies CHEM 3403. Explores the principles covered in CHEM 3403 by laboratory experimentation. Experiments include measurement of reaction kinetics, such as excited state dynamics, measurement of gas transport properties, atomic and molecular absorption and emission spectroscopy, infrared spectroscopy of molecular vibrations, and selected applications of fluorimetry.

CHEM 3431. Physical Chemistry. 4 Hours.
Offers an in-depth survey of physical chemistry. Emphasizes applications in modern research, including examples from biochemistry. Topics include the laws of thermodynamics and their molecular interpretation; equilibrium in chemical and biochemical systems; molecular transport; kinetics, including complex enzyme mechanisms; and an introduction to spectroscopy and the underlying concepts of quantum chemistry.

CHEM 3432. Lab for CHEM 3431. 1 Hour.
Accompanies CHEM 3431. Covers practical skills in physical chemistry with an emphasis on current practice in chemistry, biochemistry, and pharmaceutical science. Introduces both ab initio and biological molecular modeling, differential scanning calorimetry, polymer characterization, protein unfolding and protein/ligand binding, electronic absorption spectroscopy, and synthesis of nanoparticles or quantum dots.

CHEM 3501. Inorganic Chemistry. 4 Hours.
Presents the following topics: basic concepts of molecular topologies, coordination compounds, coordination chemistry, isomerism, electron-transfer reactions, substitution reactions, molecular rearrangements and reactions at ligands, and biochemical applications.

CHEM 3502. Lab for CHEM 3501. 1 Hour.
Offers a laboratory course in inorganic chemistry with experiments and projects that track with the topics discussed in CHEM 3501. Designed to provide laboratory experience with the synthesis of coordination compounds and with the instrumental methods used to characterize them.

CHEM 3503. Recitation for CHEM 3501. 0 Hours.
Offers students additional opportunities to work interactively with instructors and other students to learn and apply the concepts presented in CHEM 3501.

CHEM 3505. Introduction to Bioinorganic Chemistry. 4 Hours.
Explores basic concepts of molecular topologies, coordination compounds, coordination chemistry, isomerism, electron-transfer reactions, substitution reactions, molecular rearrangements, and reactions at ligands in the context of metal-based drugs, imaging agents, and metalloenzymes.

CHEM 3506. Lab for CHEM 3505. 1 Hour.
Offers a laboratory course in inorganic chemistry with experiments and projects that track with the topics discussed in CHEM 3505. Designed for students who have mastered basic laboratory techniques in general and organic chemistry. Introduces new synthetic techniques and applies modern analytical characterization tools not previously used in other laboratory courses (such as CHEM 3522 and CHEM 3532).

CHEM 3507. Recitation for CHEM 3505. 0 Hours.
Offers students additional opportunities to work interactively with instructors and other students to learn and apply the concepts presented in CHEM 3505.

CHEM 3521. Instrumental Methods of Analysis. 1 Hour.
Introduces the instrumental methods of analysis used in all fields of chemistry, with an emphasis on understanding not only the fundamental principles of each method but also the basics of the design and operation of the relevant instrumentation.

CHEM 3522. Instrumental Methods of Analysis Lab. 4 Hours.
Accompanies CHEM 3521. Lab experiments provide hands-on experience in the instrumental methods of analysis discussed in CHEM 3521, such as high-performance liquid chromatography, gas chromatography, mass spectrometry, capillary electrophoresis, atomic absorption, cyclic voltammetry, and UV-vis spectroscopy.

CHEM 3531. Chemical Synthesis Characterization. 1 Hour.
Introduces advanced techniques in chemical synthesis and characterization applicable to organic, inorganic, and organometallic compounds. Techniques used include working under inert atmosphere, working with liquefied gases, and handling moisture-sensitive reagents, NMR, IR, and UV-vis spectroscopy.

CHEM 3532. Chemical Synthesis Characterization Lab. 4 Hours.
Acompanies CHEM 3531. Covers topics from the course through various experiments.

CHEM 3990. Elective. 1-4 Hours.
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

CHEM 4456. Organic Chemistry 3: Organic Chemistry of Drug Design and Development. 4 Hours.
Offers students majoring in chemistry an opportunity to apply the principles gained in two semesters of organic chemistry and chemical biology to a relevant disciplinary context. The discovery, design, and development of biologically active compounds for medical purposes uses knowledge and techniques gained in both organic synthesis and chemical biology. It directs those skills to incorporate specific chemical features into organic compounds to meet biological criteria. As such, it seeks to develop problem-solving skills that are valuable across a range of chemical disciplines and not confined to synthetic organic chemistry alone.

CHEM 4457. Lab for CHEM 4456. 1 Hour.
Accompanies CHEM 4456. Includes literature research activities, field trips, case studies, and presentations. Offers students an opportunity to prepare for a wider range of career options.

CHEM 4460. Enzymes: Chemistry and Chemical Biology. 4 Hours.
Focuses on enzymes: their chemistry, mechanisms, and applications. Examines the underlying chemical and mechanistic principles. Introduces the techniques and approaches in enzymology. Bridges the gap between classroom learning and real-world practice in the related fields, e.g., medicinal chemistry, chemical biology, engineering, and pharmaceutical research.

CHEM 4620. Introduction to Protein Chemistry. 4 Hours.
Introduces protein chemistry in the context of molecular medicine. Discusses analytical methods used to elucidate the origin, structure, function, and purification of proteins. Surveys the synthesis and chemical properties of structurally and functionally diverse proteins, including globular, membrane, and fibrous proteins. Discusses the role of intra- and intermolecular interactions in determining protein conformation, protein folding, and in their enzymatic activity. Intended for undergraduate students without prior experience in protein chemistry.

CHEM 4621. Introduction to Chemical Biology. 4 Hours.
Probes the structure and function of biological macromolecules and the chemical reactions carried out in living systems, including biological energetics. Discusses techniques to measure macromolecular interactions and the principles and forces governing such interactions. Offers students an opportunity to gain experience in reading and evaluating primary literature. Intended for undergraduate students with no prior knowledge of the field.

CHEM 4622. Lab for CHEM 4621. 1 Hour.
Accompanies CHEM 4621. Complements and reinforces the concepts from CHEM 4621 with an emphasis on fundamental techniques. Offers students an opportunity to complete independent projects in modern chemical biology research.

CHEM 4628. Introduction to Spectroscopy of Organic Compounds. 4 Hours.
Examines the application of modern spectroscopic techniques to the structural elucidation of small organic molecules. Emphasizes the use of H and C NMR spectroscopy supplemented with information from infrared spectroscopy and mass spectrometry. Explores both the practical and nonmathematical theoretical aspects of 1D and 2D NMR experiments. Topics include the chemical shift, coupling constants, the nuclear Overhauser effect and relaxation, and 2D homonuclear and heteronuclear correlation. Designed for chemists who do not have an extensive math or physics background; no prior knowledge of NMR spectroscopy is assumed.

CHEM 4629. Identification of Organic Compounds. 2 Hours.
Introduces the use of the nuclear magnetic resonance (NMR) spectrometer and basic NMR experiments. Determines the identity of unknown organic compounds by the use of mass spectrometry, infrared spectroscopy, and 1D and 2D nuclear magnetic resonance spectroscopy.

CHEM 4700. Topics in Organic Chemistry. 4 Hours.
Offers various topics within the breadth of organic chemistry. Intended to meet the needs and interests of students. Topics could range from the physical and material aspects of organic chemistry to the biochemical and biomedical aspects of organic chemistry. May be repeated once.

CHEM 4750. Senior Research. 4 Hours.
Conducts original experimental work under the direction of members of the department on a project. Introduces experimental design based on literature and a variety of techniques depending upon the individual project.

CHEM 4770. Chemistry Capstone. 4 Hours.
Integrates and assesses both curricular and experiential aspects of undergraduate chemical education. Requires written and oral presentations related to cooperative education or other experiential activities, and to the senior research project. Reporting on the research project requires extensive library and Internet research of background and scientific principles, and organization and interpretation of results. Includes class discussion and critiquing of materials presented.

CHEM 4901. Undergraduate Research. 4 Hours.
Conducts original research under the direction of members of the department. May be repeated without limit.

CHEM 4970. Junior/Senior Honors Project 1. 4 Hours.
Focuses on in-depth project in which a student conducts research or produces a product related to the student's major field. Combined with Junior/Senior Project 2 or college-defined equivalent for 8 credit honors project. May be repeated without limit.

CHEM 4971. Junior/Senior Honors Project 2. 4 Hours.
Focuses on second semester of in-depth project in which a student conducts research or produces a product related to the student's major field. May be repeated without limit.

CHEM 4990. Elective. 1-4 Hours.
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

CHEM 4991. Research. 4 Hours.
Offers an opportunity to conduct research under faculty supervision. May be repeated without limit.

CHEM 4992. Directed Study. 1-4 Hours.
Offers independent work under the direction of members of the department on a chosen topic. Course content depends on instructor. May be repeated without limit.

CHEM 4993. Independent Study. 1-4 Hours.
Offers independent work under the direction of members of the department on a chosen topic. Course content depends on instructor. May be repeated without limit.

CHEM 5460. Enzymes: Chemistry and Chemical Biology. 3 Hours.
Focuses on enzymes: their chemistry, mechanisms, and applications. Examines the underlying chemical and mechanistic principles. Introduces the techniques and approaches in enzymology. Bridges the gap between classroom learning and real-world practice in the related fields, e.g., medicinal chemistry, chemical biology, engineering, and pharmaceutical research.

CHEM 5550. Introduction to Glycobiology and Glycoprotein Analysis. 3 Hours.
Covers the background and methods used for glycoprotein characterization. Offers students an opportunity to obtain the background needed to assess the analytical steps necessary for development of glycoprotein drugs. Analyzes regulatory issues behind glycoprotein drug development. Covers recent developments in analytical and regulatory sciences.

CHEM 5599. Introduction to Research Skills and Ethics in Chemistry. 0 Hours.
Seeks to prepare students for success in CHEM 5600 and in CHEM 7730. May be repeated once. Must be taken in consecutive semesters before registration into CHEM 5600 and CHEM 7730. .

CHEM 5600. Research Skills and Ethics in Chemistry. 3 Hours.
Discusses ethics in science. Topics include documentation of work in your laboratory notebook, safety in a chemistry research laboratory, principles of experimental design, online computer searching to access chemical literature, reading and writing technical journal articles, preparation and delivery of an effective oral presentation, and preparation of a competitive research proposal.

CHEM 5610. Polymer Chemistry. 3 Hours.
Discusses the synthesis and analysis of polymer materials. Covers mechanisms and kinetics of condensation/chain-growth polymerization reactions and strategies leading to well-defined polymer architectures and compositions, including living polymerizations (free radical, cationic, anionic), catalytic approaches, and postpolymerization functionalization. Discusses correlation of chemical composition and structure to physical properties and applications.

CHEM 5611. Analytical Separations. 3 Hours.
Describes the theory and practice of separating the components of complex mixtures in the gas and liquid phase. Also includes methods to enhance separation efficiency and detection sensitivity. Covers thin-layer, gas, and high-performance liquid chromatography (HPLC) and recently developed techniques based on HPLC including capillary and membrane-based separation, and capillary electrophoresis.

CHEM 5612. Principles of Mass Spectrometry. 3 Hours.
Describes the theory and practice of ion separation in electrostatic and magnetic fields and their subsequent detection. Topics include basic principles of ion trajectories in electrostatic and magnetic fields, design and operation of inlet systems and electron impact ionization, and mass spectra of organic compounds.

CHEM 5613. Optical Methods of Analysis. 3 Hours.
Describes the application of optical spectroscopy to qualitative and quantitative analysis. Includes the principles and application of emission, absorption, scattering and fluorescence spectroscopies, spectrometer design, elementary optics, and modern detection technologies.

CHEM 5616. Protein Mass Spectrometry. 3 Hours.
Offers students an opportunity to obtain a fundamental understanding of modern mass spectrometers, the ability to operate these instruments, and the ability to prepare biological samples. Undoubtedly the most popular analytical method in science, mass spectrometry is utilized in fields ranging from subatomic physics to biology. Focuses on the analysis of proteins, with applications including biomarker discovery, tissue characterization, detection of blood doping, drug discovery, and the characterization of protein-based therapeutics. By the end of the course, the student is expected to be able to solve a particular chemistry- or biology-related problem by choosing the appropriate sample preparation methods and mass spectrometer.

CHEM 5617. Protein Mass Spectrometry Laboratory. 3 Hours.
Offers students an opportunity to develop an appreciation of the appropriate choice of mass spectrometer for a particular application.

CHEM 5620. Protein Chemistry. 3 Hours.
Describes proteins (what they are, where they come from, and how they work) in the context of analytical analysis and molecular medicine. Discusses the chemical properties of proteins, protein synthesis, and the genetic origins of globular proteins in solution, membrane proteins, and fibrous proteins. Covers the physical intra- and intermolecular interactions that proteins undergo along with descriptions of protein conformation and methods of structural determination. Explores protein folding as well as protein degradation and enzymatic activity. Highlights protein purification and biophysical characterization in relation to protein analysis, drug design, and optimization.

CHEM 5621. Principles of Chemical Biology for Chemists. 3 Hours.
Explores the use of natural and unnatural small-molecule chemical tools to probe macromolecules, including affinity labeling and click chemistry. Covers nucleic acid sequencing technologies and solid-phase synthesis of nucleic acids and peptides. Discusses in-vitro selection techniques, aptamers, and quantitative issues in library construction. Uses molecular visualization software tools to investigate structures of macromolecules. Intended for graduate and advanced undergraduate students.

CHEM 5622. Lab for CHEM 5621. 1 Hour.
Accompanies CHEM 5621. Complements and reinforces the concepts from CHEM 5621 with emphasis on fundamental techniques. Offers an opportunity to complete independent projects in modern chemical biology research.

CHEM 5625. Chemistry and Design of Protein Pharmaceuticals. 3 Hours.
Covers the chemical transformations and protein engineering approaches to protein pharmaceuticals. Describes protein posttranslational modifications, such as oxidation, glycosylation, formation of isoaspartic acid, and disulfide. Then discusses bioconjugate chemistry, including those involved in antibody-drug conjugate and PEGylation. Finally, explores various protein engineering approaches, such as quality by design (QbD), to optimize the stability, immunogenicity, activity, and production of protein pharmaceuticals. Discusses the underlying chemical principles and enzymatic mechanisms as well.

CHEM 5626. Organic Synthesis 1. 3 Hours.
Surveys types of organic reactions including stereochemistry, influence of structure and medium, mechanistic aspects, and synthetic applications.

CHEM 5627. Mechanistic and Physical Organic Chemistry. 3 Hours.
Surveys tools used for elucidating mechanisms including thermodynamics, kinetics, solvent and isotope effects, and structure/reactivity relationships. Topics include molecular orbital theory, aromaticity, and orbital symmetry. Studies reactive intermediates including carbenes, carbonium ions, radicals, biradicals and carbanions, acidity, and photochemistry.

CHEM 5628. Principles of Spectroscopy of Organic Compounds. 3 Hours.
Studies how to determine organic structure based on proton and carbon nuclear magnetic resonance spectra, with additional information from mass and infrared spectra and elemental analysis. Presents descriptive theory of nuclear magnetic resonance experiments and applications of advanced techniques to structure determination. Includes relaxation, nuclear Overhauser effect, polarization transfer, and correlation in various one- and two- dimensional experiments. Requires graduate students to have one year of organic chemistry or equivalent.

CHEM 5636. Statistical Thermodynamics. 3 Hours.
Briefly reviews classical thermodynamics before undertaking detailed coverage of statistical thermodynamics, including probability theory, the Boltzmann distribution, partition functions, ensembles, and statistically derived thermodynamic functions. Reconsiders the basic concepts of statistical thermodynamics from the modern viewpoint of information theory. Presents practical applications of the theory to problems of contemporary interest, including polymers and biopolymers, nanoscale systems, molecular modeling, and bioinformatics.

CHEM 5638. Molecular Modeling. 3 Hours.
Introduces molecular modeling methods that are basic tools in the study of macromolecules. Is structured partly as a practical laboratory using a popular molecular modeling suite, and also aims to elucidate the underlying physical principles upon which molecular mechanics is based. These principles are presented in supplemental lectures or in laboratory workshops.

CHEM 5651. Materials Chemistry of Renewable Energy. 3 Hours.
Studies renewable energy in terms of photovoltaics, photoelectrochemistry, fuel cells, batteries, and capacitors. Focuses on the aspects of each component and their relationships to one another.

CHEM 5660. Analytical Biochemistry. 3 Hours.
Focuses on the analysis of biological molecules, which include nucleic acids, proteins, carbohydrates, lipids, and metabolites. Methods used for isolation, purification, and characterization of these molecules are discussed.

CHEM 5672. Organic Synthesis 2. 3 Hours.
Continues CHEM 5626. Surveys types of organic reactions including stereochemistry, influence of structure and medium, mechanistic aspects, and synthetic applications.

CHEM 5676. Bioorganic Chemistry. 3 Hours.
Covers host guest complexation by crown ethers, cryptands, podands, spherands, and so forth; molecular recognition including self-replication; peptide and protein structure; coenzymes and metals in bioorganic chemistry; nucleic acid structure; interaction of DNA with proteins and small molecules including DNA-targeted drug design; catalytic RNA; and catalytic antibodies.

CHEM 5700. Topics in Organic Chemistry. 3 Hours.
Offers various topics within the breadth of organic chemistry. Intended to meet the needs and interests of students. Topics could range from the physical and material aspects of organic chemistry to the biochemical and biomedical aspects of organic chemistry. Undergraduate students who have completed a second semester of organic chemistry with a grade of at least C– may be admitted with permission of instructor. May be repeated once.

CHEM 5904. Seminar. 1 Hour.
Focuses on oral reports by master of science and PlusOne participants on current research topics in chemistry and chemical biology. May be repeated up to two times.

CHEM 5976. Directed Study. 1-4 Hours.
Offers independent work under the direction of members of the department on a chosen topic. Course content depends on instructor. May be repeated without limit.

CHEM 5984. Research. 1-6 Hours.
Offers an opportunity to conduct research under faculty supervision. May be repeated up to three times for up to 6 total credits.

CHEM 6962. Elective. 1-4 Hours.
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

CHEM 7247. Advances in Nanomaterials. 3 Hours.
Designed to provide an entry-level perspective of solid-state chemistry both from a fundamental and applied perspective. Discusses the basic aspects of materials science encompassing broad areas of structure, physical properties, and classification in the context of both bulk and surface (thin films, interfaces) properties.

CHEM 7305. Special Topics in Inorganic and Materials Chemistry. 3 Hours.
Presents selected topics of current importance in inorganic and materials chemistry. May be repeated without limit.

CHEM 7317. Analytical Biotechnology. 3 Hours.
Focuses on the analytical methods used for the characterization of recombinant DNA-derived proteins for human therapeutic use. Combines the description of advanced analytical methods, in particular HPLC and mass spectrometry, with protein chemistry. An important aspect is the development of a method that can identify protein modifications that are present in a product as a result of biosynthetic modifications, contaminants, or degradative reactions. Provides an integrative overview of the role of analytical methods at the different stages of development and production of protein therapeutics including upstream (cell line development, cell culture), downstream (recovery and purifications), formulation development, stability studies, and clinical assay.

CHEM 7730. Advanced Laboratory Methods. 4 Hours.
Seeks to provide intensive practical laboratory training in a chosen thematic area. Students select from organic and medicinal chemistry, physical and materials chemistry, or analytical and biological chemistry. The course involves a common practical training module followed by specialized modules in the chosen concentration area. The practical training features a combination of formal laboratory instruction coupled with rotation through selected research laboratories. Full-time PhD students only.

CHEM 7750. Advanced Problem Solving. 3 Hours.
Designed to provide skills necessary to lead advanced problem-solving case studies. Faculty mentors in one of three thematic areas chosen from organic and medicinal chemistry, physical and materials chemistry, or analytical and biological chemistry assign casework to students for presentation and analysis in group sessions. Students are required to provide rational solutions to complex problems derived from the contemporary literature and engage in dialogue with faculty mentors to justify their analysis. The faculty mentors assign grades to reflect intellectual maturity and ability of the students to display creative, independent thinking. Full-time PhD students who have successfully completed qualifying examinations only.

CHEM 7962. Elective. 1-4 Hours.
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

CHEM 7990. Thesis. 1-4 Hours.
Offers thesis supervision by members of the department. May be repeated without limit.

CHEM 7996. Thesis Continuation. 0 Hours.
Offers continuing thesis supervision by members of the department.

CHEM 8504. Graduate Seminar. 1 Hour.
Focuses on oral reports by the participants on current research topics in chemistry and chemical biology. May be repeated without limit.

CHEM 8960. Exam Preparation—Doctoral. 0 Hours.
Offers the student the opportunity to prepare for and take the PhD qualifying exams (cumulative exams).

CHEM 8984. Research. 1-6 Hours.
Offers the chance to conduct original research, written thesis thereon, or to the establishment of doctoral candidacy. May be repeated without limit.

CHEM 8986. Research. 0 Hours.
Offers the student the opportunity to conduct full-time research for the master's degree. May be repeated without limit.

CHEM 9984. Research. 1-4 Hours.
Offers an opportunity to conduct research under faculty supervision. May be repeated without limit.

CHEM 9986. Research. 0 Hours.
Offers the student the opportunity to conduct full-time research for the PhD. May be repeated without limit.

CHEM 9990. Dissertation. 0 Hours.
Offers the student the opportunity to conduct theoretical and experimental research for the PhD degree. Open to chemical biology students. May be repeated once.

CHEM 9996. Dissertation Continuation. 0 Hours.
Offers dissertation supervision by members of the department. Open to chemical biology students. May be repeated without limit.