888. Research Survey

Fall, Winter, Spring, Summer. 1 to 3 credits. May re-enroll for a maximum of 3 credits.

Literature search, problem analysis, and layout of a complete research program.

893. Special Problems

Fall, Winter, Spring, Summer. Variable credit. Approval of department.

899. Research

Fall, Winter, Spring, Summer. Variable credit. Approval of department.

912. Advanced Chemical Engineering Thermodynamics II

Spring of even-numbered years. 3(3-0) Approval of department.

Relation of thermodynamics to quantum theory and statistical mechanics. Computation of chemical engineering thermodynamic data from spectral measurements. Irreversible thermodynamics.

918. Advanced Chemical Reaction Engineering II

Fall of odd-numbered years. 3(3-0) Approval of department.

Quantitative treatment of current literature in chemical kinetics and reaction engineering.

927. Flow of Heat II

Fall of even-numbered years. 3(3-0) Approval of department.

Fundamentals of radiant heat transfer. Computer techniques in the design of radiant and convective heat transfer equipment.

965. Special Topics in Optimal Process Theory

Spring of odd-numbered years. 3(3-0) 835 or approval of department. Interdepartmental with Systems Science.

Continuation of 835 and special topics from the literature in nonlinear, stochastic and dynamic programming.

999. Research

Fall, Winter, Spring, Summer. Variable credit. Approval of department.

CHEMISTRY CEM

College of Natural Science

Credit cannot be earned in more than one course of each of the following groups: 130 and 141, 131 and 141, 142 and 153, 132 and 241 or 351, 242 and 352, 383 and 461, 361 and 384, 394 and 472.

With department approval, students with credit in CEM 141-161 may enroll in CEM 181-184H. Those with credit in CEM 152 may enroll in CEM 182H and those with credit in CEM 153 may enroll in CEM 183H. However, students with credit in an Honors Chemistry course may not receive credit in the corresponding non-Honors Chemistry course.

130. Introductory Chemistry I

Fall, Winter, Spring, Summer. 4 credits—Self-instructional only. MTH 108 or 111 or concurrently.

General discussion of principles. Atomic and molecular structure and spectra; stoichiometry; gases, liquids, solids, solutions, and changes of state. Laboratory experiments via film, TV tape or live demonstration.

131. Introductory Chemistry II

Fall, Winter, Spring, Summer. 3 credits—Self-instructional only. 130; 161 concurrently.

Continuation of 130. Chemical kinetics and equilibrium; ionic equilibrium; acids and bases.

132. Introductory Chemistry: Carbon Compounds

Fall, Spring, Summer. 3(3-2) 131 or 141; 161.

Chemistry of carbon compounds, introducing the aliphatic and aromatic hydrocarbon series. Some typical compounds are prepared and their behavior studied.

141. Principles of Chemistry I

Fall, Winter. 4(4-0) MTH 108 or 111 or concurrently; 1 year high school chemistry; 161 concurrently.

Atomic and molecular structure, chemical kinetics and equilibrium; acids and bases. The solid state.

142. Introductory Chemistry III

Fall, Spring. 3(3-0) 131 or 141.

Reactions and behavior of inorganic compounds.

152. Principles of Chemistry II

Winter, Spring. 3(3-0) 131 or 141; MTH 112 or concurrently. Grade of C or better in 131 or 141 recommended.

Thermochemistry and applications of thermochemical principles; equilibrium and electrochemistry.

153. Introductory Inorganic Chemistry

Fall, Spring. 3(3-0) 152.

Descriptive inorganic chemistry with further discussion of bonding; introduction to radiochemistry.

161. Introductory Chemistry Laboratory

Fall, Winter, Spring, Summer. 1(0-3) 131 or 141 concurrently.

Laboratory work in chemistry including quantitative physiochemical or analytical experiments and chemical synthesis.

162. Quantitative Analysis

Fall, Winter, Spring, Summer. 3(1-6) 131 or 141; 161.

Laboratory work in quantitative chemistry.

163. Introductory Inorganic Laboratory

Spring. 2(0-6) 162.

Qualitative analysis and inorganic preparations.

181H. Honors Chemistry I—Principles

Fall. 4(4-0) A average in high school chemistry, physics and mathematics; MTH 112 or 122 concurrently. Results of examination during orientation; approval of department.

Subatomic, atomic and molecular structure; quantum theory and bonding; experimental methods of structure determination; states of matter; nuclear chemistry.

182H. Honors Chemistry II—Principles

Winter. 4(4-0) 181H with grade of 3.0 or better and/or approval of department. MTH 113 or 123 concurrently.

Kinetic theory of gases, thermodynamics, chemical equilibrium, electrochemistry, chemical kinetics, properties of solutions, macromolecular chemistry.

183H. Honors Chemistry III—Inorganic Chemistry

Spring. 3(3-0) 182H with grade of 3.0 or better and/or approval of department.

Descriptive inorganic chemistry by periodic groups of elements. Nomenclature, bonding, sterochemistry, and reactions of compounds of the representative and transition elements.

184H. Honors Chemistry Laboratory I

Fall. 1(0-3) 181H concurrently; approval of department.

Techniques of measurement; errors and significant figures; experiments related to atomic and molecular structure.

185H. Honors Chemistry Laboratory II

Winter. 2(0-6) 184H; 182H concurrently; approval of department.

Experiments related to gas behavior, thermodynamics, electro-chemistry, chemical kinetics and properties of solutions.

186H. Honors Chemistry Laboratory III

Spring. 2(0-6) Approval of department.

Introductory independent laboratory work in chemistry.

241. Organic Chemistry

Fall, Winter, Summer. 4(4-0) 131 or 141; 161.

Common classes of organic compounds with emphasis on nomenclature, structural principles, reactions and reaction mechanisms.

242. Organic Chemistry

Winter, Spring, Summer. 4(4-0) 241.

Continuation of 241 with emphasis on polyfunctional compounds, particularly groups of compounds having biological significance.

243. Organic Chemistry Laboratory

Fall, Winter, Summer. 1(0-2) 241 or concurrently.

Introduction to standard organic laboratory techniques.

244. Organic Chemistry Laboratory

Winter, Spring, Summer. 1(0-3) 241, 243, 242 concurrently.

Organic preparations and qualitative analysis.

245. Organic Chemistry

Fall, Spring. 4(4-0) 242.

Selected topics of organic chemistry, especially compounds of biological interest, discussed with emphasis on mechanisms and stereochemistry. Topics include polymers, amino acids, proteins, sugars, terpenes, steroids, and alkaloids.

333. Instrumental Methods

Spring. 4(2-6) 132 or 241 or 351; 162.

Principles, applications of separation and instrumental analysis. Atomic emission, absorption, fluorescence spectrometry; UV, visible, IR spectrophotometry; molecular fluorescence; gas and other chromotography; electro-analytical chemistry; electrophoresis; radiochemistry.

351. Organic Chemistry

Fall. 3(4-0) 152.

A comprehensive introduction to the fundamentals of organic chemistry, designed for chemistry majors but open to others who desire a rigorous, modern treatment of the subject.

352. *Organic Chemistry*
Winter. 3(4-0) 351.
Continuation of 351.

353. *Organic Chemistry*
Spring. 3(4-0) 352.
Continuation of 352.

354. *Organic Chemistry Laboratory*
Winter. 2(0-6) 162, 351.
A laboratory course in modern techniques of organic chemistry, including qualitative organic analysis.

355. *Organic Chemistry Laboratory*
Spring. 2(0-6) 352, 354.
Continuation of 354.

356. *Organic Chemistry Laboratory*
Fall. 2(0-6) 355.
Continuation of 355.

361. *Chemical Thermodynamics*
Fall. 3(4-0) One year general chemistry; one year general physics; MTH 215.
Thermodynamics. Properties of gases. Laws of thermodynamics, properties of ideal and non-ideal solutions, thermodynamics of chemical reactions, activities in non-ionic systems.

362. *Analytical-Physical Chemistry I*
Winter. 3(4-0) 361.
Applications of thermodynamics. Activity coefficients, ionic solutions, cell potentials, ionic equilibria including acid-base, complexation, solubility and redox equilibria, phase equilibria, distillation, extraction, chromatography.

363. *Analytical-Physical Chemistry II*
Spring. 3(4-0) 362.
Chemical kinetics. Homogeneous kinetics, reaction mechanisms, temperature dependence of reaction rates, transport process, heterogeneous kinetics, electrode kinetics, X-ray diffraction, crystal structure.

372. *Analytical-Physical Chemistry Laboratory I*
Winter. 2(1-3) 162; 383 or 361.
Measurement techniques. Temperature measurement and control, pressure, calorimetry, pH, acid-base titrations, cell potentials, treatment of data.

373. *Analytical-Physical Chemistry Laboratory II*
Spring. 2(1-3) 372.
Instrumental measurements. Electrode potentials, chromatography, spectrophotometry, electrolytic conductance, solution kinetics.

383. *Physical Chemistry: Introductory*
Fall, Summer. 3(4-0) 132 or 241 or 351; MTH 113.
Classical and chemical thermodynamics. Introduction to the laws and their applications in treating chemical reactions, pure substances, ideal and non-ideal mixtures, and colligative properties.

384. *Physical Chemistry: Introductory*
Winter, Summer. 3(4-0) 132 or 241 or 351; MTH 113.
Atomic and molecular structure. Atomic and molecular orbitals and chemical bonding. Rotational, vibrational and electronic spectra, nuclear magnetic resonance and electron spin resonance.

385. *Physical Chemistry: Introductory*
Spring. 3(4-0) 383 and 384.
Electrochemistry and electromotive force. Chemical kinetics. Macromolecules and biochemical systems. Nuclear chemistry.

394. *Spectroscopy Laboratory*
Spring. 2(1-3) 384 or 461.
Laboratory work in electronic, vibrational, and rotational spectroscopy, mass spectrometry, nuclear and electron spin resonance, dipole moments and magnetic susceptibility.

400H. *Honors Work*
Fall, Winter, Spring, Summer. Variable credit. Seniors, approval of department.
Assigned reading and investigation in chemistry under the supervision of the staff. The program will include some creative work.

411. *Inorganic Chemistry I*
Fall, Summer. 3(3-0) 385 or 363.
Principles of structure and bonding in inorganic chemistry, crystal symmetry, coordination chemistry, solvent systems, hydrogen bonding and selected examples from the chemistry of various elements.

412. *Inorganic Chemistry II*
Winter. 3(3-0) 411.
Inorganic chemistry viewed in a variety of examples of reactions, structure, mechanisms, etc., from representative main group elements and transition elements.

419. *Problems and Reports*
Fall, Winter, Spring, Summer. 2 to 8 credits.

430. *Introduction to Radioactivity and Radioisotope Techniques*
Spring, Summer. 2(3-0) or 3(3-0) One year each of general college chemistry and physics. Interdepartmental with and administered by the Department of Physics.
First 7 weeks. Elementary nuclear processes and properties with emphasis on radioactivity, its measurement, and its interaction with matter. Effects of radiation on chemical and biological systems. Applications of nuclear technology, safety and environmental factors. *Last 3 weeks.* Fundamentals of nuclear models, reactions and decay mechanisms. Basic principles of nuclear reactors and accelerators.

431. *Laboratory for Radioactivity and Radioisotope Techniques*
Spring, Summer. 1(0-3) 161, 430, concurrently. 162 recommended. Interdepartmental with and administered by the Department of Physics.
Introduction to nuclear instrumentation. Experimental techniques for application of radioisotopes to problems in chemistry, the life sciences, and industry.

446. *Polymerization*
Fall. 3(3-0) One year organic chemistry, elementary physical chemistry. Interdepartmental with the Department of Chemical Engineering.
Formation and characterization of polymers of high molecular weight will be emphasized.

461. *Theoretical Chemistry I*
Fall. 3(4-0) One year general chemistry; one year general physics; MTH 215.
Quantum chemistry. Wave properties, postulates of quantum mechanics, hydrogen atom, helium atom, orbital theories, ionic bonds, simple molecules, valence-bond and molecular-orbital theories, complex molecules, introduction to spectra.

462. *Theoretical Chemistry II*
Winter. 3(4-0) 361, 461.
Spectroscopy and molecular structure. Electronic, infrared, Raman, and microwave spectroscopy, magnetic susceptibility and magnetic resonance, statistical mechanics, statistical thermodynamics, kinetic theory of gases, absolute rate theory.

471. *Analytical-Physical Chemistry Laboratory III*
Fall. 2(0-6) 363, 373.
Kinetics, operational amplifiers, polarography, coulometry, electrochemical kinetics, stopped-flow kinetics, digital measurements, neutron activation.

472. *Analytical-Physical Chemistry Laboratory IV*
Winter. 2(0-6) 461, 471.
Molecular properties. Mass spectrometry, nuclear and electron spin resonance spectroscopy, infrared spectroscopy, dipole moments, magnetic susceptibility, gaseous decomposition kinetics.

484. *Modern Physical Chemistry*
Spring. 3(3-0) May re-enroll for a maximum of 6 credits if a different topic is taken. 462.
Topics may be selected from the following: physical properties and structure, molecular structure, spectroscopy, theory of solutions.

499. *Seminar on Chemical Physics*
Fall, Winter, Spring. 1(1-0) May re-enroll for a maximum of 3 credits. One year of analytical-physical chemistry. MTH 215; PHY 428.
Literature of chemical physics through oral reports on selected journal articles in the area.

810. *Advanced Inorganic Chemstry*
(812.) Fall. 3(3-0) Approval of department.
Structure, bonding and reactivity patterns of inorganic compounds, with emphasis on metallic elements and coordination chemistry in aqueous and nonaqueous media; concepts in symmetry, pseudo-rotation and other reaction mechanisms.

811. *Symmetry, Group and MO Theory*
Winter. 3(3-0) Approval of department.
Applications of group and molecular orbital theory to chemical bonding, structure and reactions.

813. *Advanced Inorganic Chemistry—Metals*
Spring. 3(3-0) 811.
Continuation of 811 with emphasis on the structure and chemistry of the metals.

830. *Nuclear and Radiochemistry*
Winter. 3(3-0) Approval of department.
Chemistry of production, isolation and identification of radionuclides and their uses in chemical research.

833. *Analytical Spectroscopy*

Winter of odd-numbered years. 3(3-0) Approval of department.

834. *Advanced Analytical Chemistry*

Fall. 3(3-0) Approval of department.

Consideration of principles and equilibria pertaining to aqueous and non-aqueous neutralization, redox and complexation reactions and the various separation techniques employed in analyses.

835. *Spectrochemical Methods of Analysis*

Winter of even-numbered years. 3(2-4) Approval of department.

Principles and applications of atomic absorption, emission, fluorescence; arc and spark emission spectroscopy; UV, visible, IR spectrophotometry; spectrophotometric titrations; reaction rate methods; molecular fluorescence, phosphorescence spectrometry; other optical spectrometric methods.

836. *Separations*

Spring of odd-numbered years. 3(3-0) Approval of department.

Physical and chemical methods of separation.

837. *Electronalytical Chemistry*

Spring of even-numbered years. 3(3-0) Approval of department.

Theory and applications of modern electroanalytical chemistry to chemical and biomedical problems. Coulometry, electrometric titrations, ion-selective voltammetry; electrochemical synthesis and preparation of species for spectroscopy; trace analysis.

838. *Scientific Instrumentation*

Fall, Spring, Summer. 2(1-3) to 4(2-6) May re-enroll for a maximum of 8 credits. Approval of department.

Scientific measurements. Principles and applications of servo systems, operational amplifiers, linear and digital solid state devices, analog, digital and hybrid instrumentation systems, and minicomputers for scientific measurements.

844. *Structural Elucidation by Instrumental Methods*

Fall. 3(3-0) Approval of department.

A practical instrumental analysis course with the major emphasis on the interpretation of data rather than a detailed description of the instrumentation. The fundamental principles behind the various measurements will be discussed in a general way, and important instrumental limitations will be noted.

847. *Physical Chemistry of Macromolecules*

Winter of odd-numbered years. 3(3-0) 446 or approval of department. Interdepartmental with and administered by the Department of Chemical Engineering.

Thermodynamics--phase equilibria of polymer solutions; configuration and conformation of chain molecules; characterization of polymer molecular weight and distribution; theoretical and experimental results for dilute solution viscosity and diffusivity; polyelectrolytes.

860. *Organic Reactions: A Mechanistic Approach*

Fall. 3(3-0) 353; 462 or approval of department.

Organic reactions are presented in a mechanistic framework. Reactions which proceed via carbocations, carbanions, free radicals, carbenes, arynes and other reactive intermediates, and concerted reactions are included.

861. *Structure of Organic Compounds*

(851.) Winter. 3(3-0) 860 or approval of department.

Structural and stereochemical principles will be developed and illustrated. Spectroscopic data will be used to illustrate the principles and to determine structure, with an emphasis on nuclear magnetic resonance spectroscopy.

862. *Advanced Synthetic Organic Chemistry*

(853.) Spring. 3(3-0) 860 or approval of department.

The strategy and methods of organic synthesis will be discussed.

863. *Physical Organic Chemistry*

(852.) Fall. 3(3-0) 860 or approval of department.

Experimental techniques and theoretical principles used to determine organic reaction mechanisms will be discussed. These include kinetics, dependence of reactivity on solvent and structure, and orbital symmetry restrictions.

880. *Atomic and Molecular Structure*

Fall. 3(3-0) 462 or approval of department.

Basic concepts of non-relativistic quantum mechanics will be developed and employed in a description of atomic and molecular structure.

881. *Thermodynamics*

Winter. 3(3-0) Approval of department.

Laws of thermodynamics and their application to pure substances and solutions.

883. *Chemical Kinetics*

Spring. 3(3-0) 880.

Rates and mechanisms of chemical reactions, reaction rate theory, kinetic theory of gases, photochemistry.

890. *Graduate Problems and Reports*

Fall, Winter, Spring, Summer. Variable credit. May re-enroll for a maximum of 12 credits. Approval of department.

899. *Research*

Fall, Winter, Spring, Summer. Variable credit. May re-enroll for a maximum of 12 credits. Approval of department.

Research in inorganic, analytical, organic, and physical chemistry.

913. *Selected Topics in Inorganic Chemistry*

Fall, Spring. 3(3-0) May re-enroll for a maximum of 9 credits if different topic is taken.

Rare earth elements, recent advances in the chemistry of metals or nonmetals, high-temperature chemistry. Coordination chemistry and nonaqueous solvents.

918. *Seminar in Inorganic Chemistry*

Fall, Winter, Spring. 0 or 1(1-0)

Discussions of recent advances and reports by graduate students on research problems.

924. *Selected Topics in Analytical Chemistry*

Fall, Winter, Spring. 3(3-0) or 2(2-0) May re-enroll for a maximum of 9 credits if different topic is taken.

Among topics which may be discussed are: advances in electroanalytical chemistry or spectroscopy; nonaqueous solvents; complexation equilibria; surface chemistry; analytical chemistry of polymers.

938. *Seminar in Analytical Chemistry*

Fall, Winter, Spring. 0 or 1(1-0)

Discussions of recent advances and reports by graduate students on research problems.

956. *Selected Topics in Organic Chemistry*

Fall, Winter, Spring. 2(2-0) or 3(3-0) May re-enroll for a maximum of 12 credits if different topic is taken. Approval of department.

Topics may be selected from heterocyclic chemistry, natural products, free radicals, carbonium ions, organic sulfur or nitrogen compounds, acidity functions, isotope effects, photochemistry and others.

958. *Seminar in Organic Chemistry*

Fall, Winter, Spring. 0 or 1(1-0)

Discussions of recent advances and reports by graduate students on research problems.

985. *Statistical Thermodynamics*

Winter of even-numbered years. Spring. 3(3-0) May re-enroll for a maximum of 9 credits if different topic is taken. Approval of department.

Partition functions, spectroscopic measurements and thermodynamic applications. Nonequilibrium statistical mechanics and thermodynamics. Time correlation functions and spectroscopic lineshapes, light scattering, and magnetic relaxation. Transport properties of fluids and gases.

987. *Selected Topics in Physical Chemistry*

Fall, Winter. 3(3-0) May re-enroll for a maximum of 9 credits if different topic is taken. Approval of department.

Mathematical preparation for quantum chemistry. Selected topics as: kinetics and photochemistry, macromolecular and surface chemistry, molecular spectroscopy, electro and magnetic properties of matter, application of statistical mechanics to chemical problems.

988. *Selected Topics in Physical Chemistry*

Winter, Spring. 3(3-0) May re-enroll for a maximum of 9 credits if different topic is taken. Approval of department.

Topics may be chosen from analysis and interpretation of the spectra of molecules, advanced molecular structure, magnetic resonance, spectroscopy, X-rays and crystal structure, statistical mechanics.

991. *Selected Topics in Quantum Chemistry*

Fall, Winter. 3(3-0) May re-enroll for a maximum of 9 credits if different topic is taken. Approval of department.

Principles of quantum mechanics and application to chemical problems. Selected topics from spectroscopy, properties of atoms and molecules in electric and magnetic fields, and theories of molecular electronic structure.

998. *Seminar in Physical Chemistry*

Fall, Winter, Spring. 0 or 1(1-0)

Discussions of recent advances and reports by graduate students on research problems.

999. *Research*

Fall, Winter, Spring, Summer. Variable credit. Approval of department.

Research in analytical, inorganic, organic, and physical chemistry.