826. *Flow of Heat I*

Spring. 3(3-0) 307.

Steady and unsteady state heat transfer. Conduction and convection in flow and non-flow systems.

828. *Optimization of Static Nonlinear Systems*

Summer. 4(4-0) Students may not receive credit for both CHE 828 and MGT 835. 465 or knowledge of linear programming. Interdepartmental with and administered by Systems Science.

Problem formulation, classification, convexity and applications; Kuhn-Tucker theory in nonlinear programming; constrained and unconstrained problems; techniques for quadratic, integer and geometric programming; gradient and search techniques.

831. *Distillation, Absorption, and Extraction—Ideal Stages*

Fall. 3(3-0) 307. May precede or follow 832.

Stagewise calculations in distillation, absorption, and extraction processes. Computer techniques. Liquid-gas and liquid-liquid equilibria. Batch, continuous, binary and multi-component calculations.

832. *Distillation, Absorption and Extraction—Phase Contactors*

Winter. 3(3-0) 307. May precede or follow 831.

Mass transfer in distillation, absorption, and extraction processes. Continuous and stagewise phase contactors. Column hydrodynamics and plate efficiency.

841. *Advanced Transport Phenomena*

Winter. 3(3-0) MTH 215, B.S. in engineering or physical science.

Use of equations of change in solving engineering problems. Boundary layer and penetration theories of interphase transport. Potential flow. Theories of turbulence from statistical standpoint.

847. *Physical Chemistry of Macromolecules*

Winter of odd-numbered years. 3(3-0) 446 or approval of department. Interdepartmental with the Chemistry Department.

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.

881. *Seminar*

Fall, Winter, Spring, Summer. 1(0-2) May re-enroll for a maximum of 3 credits allowed toward M.S. degree and 6 credits toward Ph.D. degree.

Detailed library investigation of one or more specialized aspects of chemical engineering, such as recent theoretical developments in one of the unit operations; presentations of these studies to a seminar group. Participation generally required each term of residence.

886. *Selected Topics in Chemical Engineering*

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

A newly developing area of chemical engineering selected by the department for offering each term. Information on the specific topic to be covered should be obtained from the department office before registration.

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*

(EGR 899.) 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) 828 or approval of department. Interdepartmental with Systems Science.

Continuation of 828 and special topics from the literature in nonlinear, stochastic, and dynamic programming.

999. *Research*

(EGR 999.) 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.

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.

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, caloimetry, 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 Chemical Engineering Department.
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.

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.

812. Advanced Inorganic Chemistry—Non-Metals
Winter. 3(3-0) 811 or approval of department.
Continuation of 811 with emphasis in structure and chemistry of the non-metals.

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.

834. Advanced Analytical Chemistry

Winter. 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

Fall. 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(2-3) 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

Winter, Spring, Summer. 4(3-4) May re-enroll for a maximum of 12 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 Chemical Engineering Department.

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.

851. Structure and Reactivity of Organic and Inorganic Compounds

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

Chemical principles will be illustrated through a coordinated presentation of examples from inorganic and organic chemistry. About half of the course will be devoted to bonding and stereochemistry, the remainder to reactive intermediates in chemical reactions and their reactivity patterns.

852. Advanced Mechanistic Organic Chemistry

Winter. 3(3-0) 851.

Continuation of 851.

853. Advanced Synthetic Organic Chemistry

Spring. 3(3-0) 852.

Continuation of 852.

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. 2(2-0) May re-enroll for a maximum of 6 credits if different topic is taken.

Among topics which may be discussed are: advances in electro-analytical chemistry or spectroscopy; non-aqueous solvents in analytical chemistry; theory of acid-base and complexation equilibria.

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

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

Definition of partition function; translational, rotational, vibrational and electronic partition functions and their calculation and application to thermodynamic problems; application of spectroscopic measurements to thermodynamic calculations.

987. Selected Topics in Physical Chemistry

Fall. 3(3-0) May re-enroll for a maximum of 6 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. 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. Quantum Chemistry

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

Principles of quantum chemistry and their application to chemical problems. Electronic structure of molecules and its correlation with the chemical and physical properties of substances. Emission and absorption of radiation.

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.