835. Nonlinear Optimization Models
Winter, Summer, 3(3..0) MTH 835. Students may not receive credit for both SYS 835 and MGT 835. MTH 215 or MTH 228, MGT 834 or CHE 485. Interdepartmental with Systems Science and the Department of Management. Jointly administered by Systems Science and the Department of Management.

836. Flow of Heat I
Spring, 3(3-0) CHE 307.
Steady and unsteady state heat transfer. Conduction and convection in flow and non-flow systems.

831. Distillation, Absorption, and Extraction—Ideal Stages
Fall, 3(3-0) CHE 307. May precede or follow CHE 332.

832. Distillation, Absorption and Extraction—Phase Contractors
Winter, 3(3-0) CHE 307. May precede or follow CHE 331.
Mass transfer in distillation, absorption, and extraction processes. Continuous and stagewise phase contractors. Column hydraulics and plate efficiency.
163. Introductory Inorganic Laboratory
Spring 2(0-6) CEM 162 or approval of department.
Qualitative analysis and inorganic preparations.

181H. Honors Chemistry I--Principles
Fall. 4(4-0) An A average in high school chemistry, physics and mathematics; MTH 112 or MTH 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 III--Inorganic Chemistry
Winter. 3(0-6) CEM 182H with grade of 3.0 or better and/or approval of department. Descriptive inorganic chemistry by periodic groups of elements. Nomenclature, bonding, stereochemistry, and reactions of compounds of the representative and transition elements.

184H. Honors Chemistry Laboratory I
Fall. 1(0-3) CEM 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) CEM 184H; CEM 182H concurrently; approval of department. Experiments related to gas behavior, thermodynamics, electrochemistry, 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) CEM 131 or CEM 141 or CEM 171 or CEM 181H; CEM 161 or CEM 184H.
Common classes of organic compounds with emphasis on nomenclature, structural principles, reactions and reaction mechanisms.

242. Organic Chemistry
Winter, Spring, Summer. 4(4-0) CEM 241.
Continuation of CEM 241 with emphasis on multifunctional compounds, particularly groups of compounds having biological significance.

243. Organic Chemistry Laboratory
Fall, Winter, Summer. 1(0-2) CEM 241 or concurrently.
Introduction to standard organic laboratory techniques.

244. Organic Chemistry Laboratory
Winter, Spring, Summer. 1(0-3) CEM 241, CEM 243, CEM 242 concurrently.
Organic preparations and qualitative analysis.

245. Organic Chemistry
Fall. Spring. 4(4-0) CEM 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(2-4) CEM 352 or CEM 354; CEM 162;
Principles, applications of separation and instrumental analysis. Atomic emission, absorption, fluorescence spectrometry; UV, visible, IR, spectrofluorometry, molecular fluorescence; gas and other chromatography; electro-analytical chemistry; electrochemistry; radiochemistry.

351. Organic Chemistry
Fall. 3(4-0) CEM 152 or CEM 182H.
A comprehensive introduction to the fundamentals of organic chemistry designed for chemists majoring open to others who desire a rigorous, modern treatment of the subject.

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

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

354. Organic Chemistry Laboratory
Winter. 2(0-6) CEM 182 or CEM 182H; CEM 351.
A laboratory course in modern techniques of organic chemistry, including qualitative organic analysis.

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

356. Organic Chemistry Laboratory
Fall. 2(0-9) CEM 355.
Continuation of CEM 355.

361. Chemical Thermodynamics
Fall. 3(4-0) One year general chemistry; one year general physics; MTH 113.

362. Analytical-Physical Chemistry I
Winter. 3(4-0) CEM 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) CEM 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) CEM 162, CEM 363, or CEM 361.
Measurement techniques. Temperature measurement, transport properties, chromatography, acid-base titrations, cell potentials, treatment of data.

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

383. Physical Chemistry: Introductory
Fall, Summer. 3(4-0) CEM 132 or CEM 241; CEM 131, 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.

394. Physical Chemistry: Introductory
Spring. 3(4-0) CEM 383.
Atomic and molecular structure. Atomic and molecular orbits and chemical bonding. Rotational, vibrational and electronic spectra, nuclear magnetic resonance and electron spin resonance.

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. 3(3-0) CEM 355 or CEM 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) CEM 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 Radiisotope 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 Radiisotope Techniques
   Spring, Summer. 10(0-3) CEM 161, PHY 430, concurrently. CEM 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.

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) CEM 361, CEM 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(4-0) CEM 362, CEM 373. Kinetics, operational amplifiers, polarography, conductometry, electrochemical kinetics, stopped-flow kinetics, digital measurements, neutron activation.

472. Analytical-Physical Chemistry Laboratory IV
   Winter. 2(0-6) CEM 461, CEM 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(0-0) May reenroll for a maximum of 6 credits if a different topic is taken. CEM 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(0-0) May reenroll 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 Chemistry
   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) CEM 811. Continuation of CEM 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. 3(3-0) Approval of department.

834. Advanced Analytical Chemistry
   Fall. 3(4-0) 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. 3(2-4) Approval of department. Principles and applications of atomic absorption, emission, fluorescence; arc and spark emission spectroscopy; UV, visible, IR spectroscopy; spectrophotometry, spectrophotometric titrations; reaction rate methods, molecular fluorescence, phosphorescence-spectroscopy, other optical spectrometric methods.

836. Separations
   Spring of odd-numbered years. 3(3-0) Approval of department. Physical and chemical methods of separation.

837. Electroanalytical Chemistry
   Spring of even-numbered years. 3(3-0) Approval of department. Theory and applications of modern electroanalytical chemistry to chemical and biomedical problems. Conductometry, electrochemical titrations, non-selective voltammetry; electrochemical synthesis and preparation of species for spectroscopy, trace analysis.

838. Scientific Instrumentation
   Fall, Spring, Summer. 2(1-3) or 4(2-5). May reenroll for a maximum of 10 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
   Spring. 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) CEM 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. Approved through Fall 1982.

   Fall. 3(3-0) CEM 353; CEM 462 or approval of department. Organic reactions are presented in a mechanistic framework. Reactions which proceed via carbonations, carbenes, free radicals, carbenes, yrones and other reactive intermediates, and concerted reactions are included.

861. Structure of Organic Compounds
   Winter. 3(3-0) CEM 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
   Spring. 3(3-0) CEM 860 or approval of department. The strategy and methods of organic synthesis will be discussed.

880. Atomic and Molecular Structure
   Fall. 3(3-0) CEM 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.

882. Chemical Kinetics
   Spring. 3(3-0) CEM 880. Rates and mechanism of chemical reactions, reaction rate theory, kinetic theory of gases, photochemistry.

890. Graduate Problems and Reports
   Fall, Winter, Spring, Summer. Variable credit. May reenroll for a maximum of 12 credits. Approval of department.

899. Master's Thesis Research
   Fall, Winter, Spring, Summer. Variable credit. Approval of department. Research in inorganic, analytical, organic, and physical chemistry.

913. Selected Topics in Inorganic Chemistry
   Fall. 3(3-0) May reenroll for a maximum of 9 credits if a different topic is taken. Rare earth elements, recent advances in the chemistry of metals or nonmetals, high-temperature chemistry. Coordination chemistry and monoxonal solvents.
<table>
<thead>
<tr>
<th>Course Title</th>
<th>Description</th>
<th>Credits</th>
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<tbody>
<tr>
<td>918. Seminar in Inorganic Chemistry</td>
<td>Fall, Winter, Spring. 1(0-0) May reenroll for a maximum of 3 credits. Discussions of recent advances and reports by graduate students on research problems.</td>
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<tr>
<td>924. Selected Topics in Analytical Chemistry</td>
<td>Fall, Winter, Spring. 3(0-0) or 2(2-0) May reenroll for a maximum of 9 credits if different topic is taken. Topics may be discussed as: advances in electroanalytical chemistry or spectroscopy, nonaqueous solvents, complexation equilibria; surface chemistry; analytical chemistry of polymers.</td>
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<tr>
<td>938. Seminar in Analytical Chemistry</td>
<td>Fall, Winter, Spring. 3(1-0) May reenroll for a maximum of 3 credits. Discussions of recent advances and reports by graduate students on research problems.</td>
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<tr>
<td>956. Selected Topics in Organic Chemistry</td>
<td>Fall, Winter, Spring. 2(2-0) or 3(0-0) May reenroll for a maximum of 12 credits if different topic is taken. 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.</td>
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<tr>
<td>958. Seminar in Organic Chemistry</td>
<td>Fall, Winter, Spring. 1(2-0) May reenroll for a maximum of 3 credits. Discussions of recent advances and reports by graduate students on research problems.</td>
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<tr>
<td>991. Selected Topics in Quantum Chemistry</td>
<td>Fall, Winter. 3(0-0) May reenroll for a maximum of 6 credits if different topic is taken. 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.</td>
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<tr>
<td>998. Seminar in Physical Chemistry</td>
<td>Fall, Winter, Spring. 1(1-0) May reenroll for a maximum of 3 credits. Discussions of recent advances and reports by graduate students on research problems.</td>
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<tr>
<td>999. Doctoral Dissertation Research</td>
<td>Fall, Winter, Spring, Summer. Variable credit. Approvals of department. Research in analytical, inorganic, organic, and physical chemistry.</td>
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**CHINESE**

See Linguistics and Oriental and African Languages.

**CIVIL AND SANITARY ENGINEERING**

**Civil Engineering**

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<tr>
<td>251. Elementary Surveying</td>
<td>Fall, Spring. 4(3-3) Not open to majors. Use of the tape, compass, level, and transit with simple maps; traverse closure and area computations; profile, cross section and stadia surveys, U.S. land system.</td>
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<tr>
<td>252. Surveying I</td>
<td>Fall, Spring. 5(4-3) Engineering majors or approval of department. Instruments, theory of measurements, error analysis, stadia, horizontal and vertical curves, U.S. Public Land System, observation for meridian.</td>
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<tr>
<td>280. Introduction to Environmental Engineering</td>
<td>Fall, Winter, Spring. 4(4-0) CEM 141, or CEM 131, MTH 112, CPS 130. Hydrology, ground water and surface water supply systems, wastewater treatment, methods of pollution control for solid waste, air, and noise.</td>
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<tr>
<td>305. Structural Mechanics I</td>
<td>Winter, Spring. 4(4-0) MTH 211. Stability and determinancy of structures. Two and three dimensional determinate structures. Indeterminate structural analysis by displacement and force methods based upon equilibrium, compatibility and load-deformation relations.</td>
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<tr>
<td>308. Engineering Materials I</td>
<td>Winter, Spring. 4(3-3) MTH 211 or concurrently. Structure; composition, physical, mechanical and rheological properties of non-metallic construction materials. Emphasis on aggregates, asphalt, inorganic cements, concrete, and wood.</td>
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<tr>
<td>311. Urban Utilities</td>
<td>Winter of odd-numbered years. 3(0-0) Capacities, limitations and cost of public and semi-public utilities as they relate to the planning and design of the urban environment. Topics include transportation, water supply, storm drainage, sewage collection and treatment, solid waste and municipal finance.</td>
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<tr>
<td>312. Soil Mechanics I</td>
<td>Spring, Summer. 4(3-3) MTH 211. Engineering properties of soils and their measurement, effective stress concept; permeability; fluid flow in soils; stress-strain behavior; soil strength; compaction and consolidation of soils; field exploration and design problems.</td>
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<tr>
<td>321. Introductory Fluid Mechanics</td>
<td>Fall, Winter, Spring. 5(4-2) MMM 306. Fluid properties, hydrostatics; control volume approach to conservation of mass, momentum and energy; dimensional analysis and dynamic similarity; fluid resistance; pipe and open channel flows; boundary layer concepts.</td>
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<tr>
<td>342. Survey of Transportation Systems</td>
<td>Fall. 4(4-0) Juniors; not open to majors. Survey of engineering aspects of all forms of transportation with emphasis on highway transportation including highway systems, planning, economic and financial aspects, geometrics and traffic studies.</td>
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<tr>
<td>346. Transportation</td>
<td>Winter, Spring. 3(3-0) MTH 113. Planning, design and evaluation of transportation systems. Operational characteristics of transportation modes, traffic flow and techniques for system selection.</td>
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<tr>
<td>347. Transportation Facilities</td>
<td>Fall. Winter. 4(3-2) CEM 252. Geometric design of highways and airports as these considerations affect capacity, construction costs, financing and safety.</td>
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<tr>
<td>353. Surveying II</td>
<td>Spring. 4(3-3) CEM 251 or CEM 252. Continuation of CEM 252 including photogrammetric methods, astronomical observations for latitude, longitude and meridian. Introduction to geodetic methods.</td>
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<tr>
<td>370. Cost and Optimization Engineering</td>
<td>Fall, Winter. 3(3-0) MTH 113. Formulation of engineering decisions governed by current and future costs and returns. Comparison and optimization of alternative engineering projects, products and processes.</td>
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<tr>
<td>372. Construction Estimating</td>
<td>Fall, Spring. 3(3-0) Juniors. Cost studies of construction activities with emphasis on labor productivity and operating characteristics of equipment under various site conditions. Interpretation of drawings and specifications.</td>
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