809. Chemical Process Design
   Summer. 4(3-2) B.S. with a major in chemistry, biochemistry, or a closely allied area. CHE 805 and CHE 807. Not open to stu-
dents with B.S. in chemical engineering for graduate credit.
   Integrated design of complete processes. Flow-sheets. Instrumentation. Optimization of equi-
   chemical and microbiological processes.

811. Advanced Chemical Engineering Thermodynamics I
   Fall. 3(3-0) CHE 311, CHE 411. CEM 361.
   Advanced treatment of the laws of thermodynamics. Cryogenic processes. Corresponding
   state and higher parameters in computing properties of chemical compounds and solu-
   tions.

817. Advanced Chemical Reaction Engineering I
   Winter. 3(3-0) CHE 428.
   Treatment of absorption and catalysis and their application to catalytic reactors. Heat, momen-
tum, and mass transfer in fixed-bed and fluidized-bed reactors. Noncatalytic heterogen-
ous reactions. Homogeneous chain reactions and free radical mechanisms. Computer applica-
tions to solution of complex kinetic problems.

826. Flow of Heat I
   Spring. 3(3-0) CHE 307.
   Steady and unsteady state heat transfer. Conduc-
ton 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 832.
   Stagewise calculations in distillation, absorption, and extraction processes. Computer tech-

832. Distillation, Absorption and Extraction--Phase Contractors
   Winter. 3(3-0) CHE 307. May precede or follow CHE 832.
   Mass transfer in distillation, absorption, and ex-

835. Nonlinear Optimization Models
   SYS 826. Winter, Summer. 4(4-0)
   Students may not receive credit for both SYS 835 and MGT 835. CHE 465 or MGT 534 or
   knowledge of linear programming. Inter-
departmental with Systems Science and the Department of Management. Jointly adminis-
tered by Systems Science and the Department of Management.
   Nonlinear optimization-examples and applica-
tions. Khan-Tucker Theory. Saddle point opti-
mality conditions. Algorithms for problems with constraints. Unconstrained optimization; in-
duction to search methods.

841. Advanced Transport Phenomena
   Spring. 3(3-0) MTH 215, B.S. in en-
ingineering 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 stand-
   point.

847. Physical Chemistry of Macromolecules
   Winter of odd-numbered years. 3(3-0)
   CHE 446 or approval of department. Inter-
departmental with the Department of Chemis-
   try.
   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 vis-
cosity and diffusivity; polyelectrolytes.

881. Seminar
   Fall, Winter, Spring, Summer. 1(0-2)
   May reenroll for a maximum of 3 credits al-
lowed 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 gen-
   erally required to each term of residence.

886. Selected Topics in Chemical Engineering
   Fall, Winter, Spring. 3(3-0)
   May reenroll for a maximum of 6 credits if a
different topic is taken.
   A newly developing area of chemical engineer-
ing selected by the department for offering each
term. Information on the specific topic to be
covered should be obtained from the depart-
ment office before registration.

888. Research Survey
   Fall, Winter, Spring, Summer. 1 to 3
   credits. May reenroll for a maximum of 3 cred-
   its. Literature search, problem analysis, and layout
   of a complete research program.

893. Special Problems
   Fall, Winter, Spring, Summer. Vari-
able credit. Approval of department.

899. Master's Thesis Research
   Fall, Winter, Spring, 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 chem-
ical engineering thermodynamic data from spectral measurements. Irreversible thermo-
dynamics.

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 convec-
tive heat transfer equipment.

999. Doctoral Dissertation Research
   Fall, Winter, Spring. Variable credit. Approval of department.

CHEMISTRY

College of Natural Science
Credit cannot be earned in more than one course of each of the following groups:

130. Introductory Chemistry I
   Fall, Winter, Spring. 4 credits-Self-instructional only. MTH 108 or
   MTH 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. 3 credit-Self-instructional only. CEM 130, CEM
   161 concurrently.
   Continuation of CEM 130. Chemical kinetics and equilibria; ionic equilibria; acids and
   bases.

132. Introductory Chemistry: Carbon Compounds
   Fall, Spring, Summer. 4(3-3) CEM 131 or
   CEM 141; CEM 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 MTH
   111 or concurrently; 1 year high school chemis-
   try. CEM 161 concurrently.
   Atomic and molecular structure, chemical kinet-
   ics and equilibria; acids and bases. The solid
   state.

142. Introductory Chemistry III
   Fall, Spring. 3(3-0) CEM 131 or CEM
   141.
   Reactions and behavior of inorganic com-
   pounds.

152. Principles of Chemistry II
   Winter. Spring. 3(3-0) CEM 131 or
   CEM 141; MTH 112 or concurrently. Grade of C
   or better in CEM 131 or CEM 141 recom-
   mended.
   Thermochimistry and applications of thermochemical principles; equilibria and
electrochemistry.

153. Introductory Inorganic Chemistry
   Fall, Spring. 3(3-0) CEM 153.
   Descriptive inorganic chemistry with further
discussion of bonding, introduction to radioc

161. Introductory Chemistry Laboratory
   Fall, Winter, Spring. 1(0-3)
   CEM 131 or CEM 141 concurrently.
   Laboratory work in chemistry, including quan-
titative physiochemical or analytical experi-
mental and chemical synthesis.

A-35
162. Quantitative Analysis
Fall, Winter, Spring, Summer. 3(1-5)
CEM 131 or CEM 141; CEM 161.
Laboratory work in quantitative chemistry.

163. Introductory Inorganic Laboratory
Spring 2(0-6) CEM 162.
Qualitative analysis and inorganic preparations.

161H. Honors Chemistry I--Principles
Fall. 4(4-0) An average in high school chemistry, physics and mathematics; MTH 112 or MTH 122 concurrently. Results of examination during orientation: approval of department.

182H. Honors Chemistry II--Principles
Winter. 4(4-0) CEM 181H with grade of 3.0 or better and/or approval of department. MTH 112 or MTH 122 concurrently. Kinetic theory of gases, thermodynamics, chemical equilibrium, electrochemistry, chemical kinetics of solutions, macromolecular chemistry.

183H. Honors Chemistry III--Inorganic Chemistry
Spring. 3(3-0) CEM 182H with grade of 3.0 or better and/or approval of department. Descriptive inorganic chemistry by periodic and transition elements.

154H. Honors Chemistry Laboratory I
Fall. 1(0-3) CEM 181H concurrently; approval of department.

155H. 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 of solutions.

186H. Honors Chemistry Laboratory III
Spring. 2(0-6) Approval of department.

241. Organic Chemistry
Fall, Winter, Summer. 4(4-0) CEM 131 or CEM 141; CEM 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) CEM 241.
Continuation of CEM 241 with emphasis on polyfunctional 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 chemical activity and selected examples from the chemistry of the representative and transition elements.

246. Organic Chemistry
Winter. 4(4-0) CEM 241, GEM 243, CEM 242 concurrently.
Continuation of CEM 241.

247. Analytical-Physical Chemistry I
Winter. 3(3-0) CEM 361.

248. 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.
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. Fundamental nuclear models, reactions and decay mechanisms. Basic principles of nuclear reactors and accelerators.

431. Laboratory for Radioactivity and Radioisotope Techniques
Spring, Summer. 10(3-0) CEM 151, PHY 430, concurrent 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. 20(0-0) CEM 363, CEM 373. Kinetics, operational amplifiers, polarography, coulometry, electrochemical kinetics, stopped-flow kinetics, digital measurements, neutron activation.

472. Analytical-Physical Chemistry Laboratory IV
Winter. 20(0-0) 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(3-0) 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 in Chemical Physics
Fall, Winter, Spring. 1(1-0) May reenroll for a maximum of 3 credits. One year of analytical-physical chemistry. MTH 215, PHY 249. Literature of chemical physics through oral reports on selected journal articles in the area.

810. Advanced Inorganic Chemistry
Fall, Spring. 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 of odd-numbered years. 3(3-0) Approval of department. Principles and applications of atomic and molecular spectroscopy, including emission, fluorescence, UV, visible, IR, Raman, nuclear magnetic resonance spectroscopy, other optical spectrometric methods.

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. 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. Coulometry, electrokinetic 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(2-5) May reenroll 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
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.

Fall. 3(2-0) CEM 355, CEM 462 or approval of department. Organic reactions are presented in a mechanistic framework. Reactions involving carbocations, carbocations, free radicals, carbonium, amines 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.

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

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

899. Master's Thesis Research
Fall, Winter, Spring. Variable credit. Approval of department. Research in inorganic, analytical, organic, and physical chemistry.
913. Selected Topics in Inorganic Chemistry
Fall, Spring, 3(3-0) May reenroll for a maximum of 9 credits if different topic is taken. 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.

918. Seminar in Inorganic Chemistry
Fall, Winter, Spring, 1(1-0) May reenroll for a maximum of 9 credits if different topic is taken. 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 reenroll for a maximum of 9 credits if different topic is taken. Among topics which may be discussed are: analytical chemistry; nonaqueous solvents; surface chemistry; analytical chemistry of polymers.

938. Seminar in Analytical Chemistry
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.

956. Selected Topics in Organic Chemistry
Fall, Winter, Spring, 2(2-0) or 3(3-0) May reenroll for a maximum of 12 credits if different topic is taken. Approval of department.

985. Statistical Thermodynamics
Winter of even-numbered years, Spring, 3(3-0) May reenroll for a maximum of 9 credits if different topic is taken. Approval of department.

988. Seminar in Physical Chemistry
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.

999. Doctoral Dissertation Research
Fall, Winter, Spring, Summer. Variable credit. Approval of department.

CHINESE
See Linguistics and Oriental and African Languages.

CIVIL AND SANITARY ENGINEERING

College of Engineering

Civil Engineering

251. Elementary Surveying
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.

252. Surveying I
Fall, Spring, 3(3-3) 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.

280. Introduction to Environmental Engineering
Fall, Winter, Spring, 4(4-0) CEM 141, or CEM 131, MTH 118, CPS 120. Hydrology; ground water and surface water supply systems; wastewater treatment, methods of pollution control for solid waste, air, and noise.

365. Structural Mechanics I
Winter, Spring, 4(4-0) MMM 211. Stability and determinacy of structures. Two and three dimensional determinate structures. Indeterminate structural analysis by displacement and force methods based upon equilibrium, compatibility and load-deformation relations.

308. Engineering Materials I
Winter, Spring, 4(3-3) MMM 211 or concurrently. Structure; composition, physical, mechanical and rheological properties of non-metallic construction materials. Emphasis on aggregates, asphalt, inorganic cements, concrete, and wood.

311. Urban Utilities
Winter of odd-numbered years, 3(3-0) 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.

321. Introductory Fluid Mechanics
Fall, Winter, Spring, 4(4-2) MMM 306. Fluid properties; hydraulics; 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.

342. Survey of Transportation Systems
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.

346. Transportation
Fall, Winter, Summer, 3(3-0) MTH 113. Planning, design and evaluation of transportation systems. Operational characteristics of transportation modes, traffic flow and techniques for system selection.

347. Transportation Facilities
Winter, 3(3-3) C E 251 or C E 252. Geometric design of highway and airport facilities as these considerations affect capacity, traffic control and economics of transport systems. Financing and administration of transport systems.

353. Surveying II
Spring, 4(3-3) C E 251 or C E 252. Continuation of C E 252 including photogrammetric methods; astronomic observations for latitude, longitude and meridian. Introduction to geodetic methods.

370. Cost and Optimization Engineering
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.