805**.** ***Transport and Separation Processes
Summer. 3(02-02)
R: Approval of department.
Momentum, energy, and mass transfer. Laminar and turbulent flow. Fluid friction.Dimensional analysis. Heat transfer in stationary and flowing materials. Interchanges. Condensation. Boiling. Binary and multicomponent distillation, absorption, extraction.
QA: CHE 807

821**.** ***Advanced Chemical Engineering Thermodynamics
Fall. 3(03-00)
R: Open only to Chemical Engineering majors.
Laws of thermodynamics, unsteady state processes. Prediction and correlation of phase equilibria for nonelectrolytes. Relation of quantum theory and statistical mechanics to thermodynamic properties.
QA: CHE 811 CHE 912

822**.** ***Transport Phenomena
Fall. 3(03-00)

Derivation of balance equations for mass, energy, and momentum. Constitutive equations for multicomponent fluids. Estimates of transport properties. Approximate models for turbulent and boundary layer flows. Boundary value problems.
QA: CHE 850 CHE 851

831**.** ***Advanced Chemical Reaction Engineering
Spring. 3(03-00)
R: Engineering
Characterization of solid catalysts. Heterogeneous reaction rate expressions. Simultaneous mass and heat transport and chemical reaction in porous catalysts. Design of fixed-bed and fluidized-bed reactors. Industrial catalytic reactions.
QA: CHE 817 CHE 918

882**.** ***Advanced Biochemical Engineering
Fall. 3(03-00)
P: CHE 481 R: Senior and above
Microbial strain improvement. Metabolic engineering. Structured growth models. Non-ideal bioreactor performance. Biosensors and process control of bioreactors. Separations processes for biochemical processing

890**.** ***Special Problems
Fall, Spring, Summer. 1 to 3 credits. May reenroll for a maximum of 6 credits.
R: Open only to graduate students in Chemical Engineering. Approval of department.
Supervised individual investigation of a problem in chemical engineering.
QA: CHE 893

891**.** ***Selected Topics(MTC)
Fall, Spring, Summer. 3(03-00) May reenroll for a maximum of 6 credits.
R: Graduate Students Engineering or Natural Science Chemical Engineering or Related Discipline
Subtitles: Swirling Flows, Stability of Reactions and Transport Processes.
QP: CHE 886

891A**.** ***Swirling Flows
Fall, Spring, Summer. 3(03-00)
R: Graduate Students Engineering or Natural Science Chemical Engineering or Related Discipline
The physical and mathematical principles governing swirling flows of Newtonian fluids are developed and used to interpret the behavior of cyclone separations and combustors.

891B**.** ***Stability of Reactions and Transport Processes
Fall, Spring, Summer. 3(03-00)
R: Graduate Students Engineering or Natural Science Chemical Engineering or Related Discipline
An analysis of stability problems in reactor dynamics and fluid mechanics using perturbation methods and Liapunov's direct method. A review of the experimental foundation for instabilities in transport processes.

899**.** ***Master's Thesis Research
Fall, Spring, Summer. 1 to 8 credits. May reenroll for a maximum of 18 credits.
R: Open only to graduate students in Chemical Engineering.

972**.** ***Viscoelasticity and Flow of Polymeric Materials
Spring of odd-numbered years. 3(03-00)
P: CHE 431
Time dependent and steady flow properties of polymeric materials related to molecular and structural parameters. Examples of polymeric blends and composites with the thermoplastic and thermoset components.
QA: CHE 860

973**.** ***Advanced Polymer Reaction Engineering
Spring of even-numbered years. 3(03-00)
P: CHE 831 R: Graduate Students in Chemical Engineering
Principles of chain polymerization and network forming reactions. Emulsion and suspension polymerization vs. graft reactions on bulk polymers. Reactor design. Morphology in polymer alloys; effects of mixing on polymer reactions.

974**.** ***Material Surfaces and Interfaces
Fall of odd-numbered years. 3(03-00) Interdepartmental with the Department(s) of Metallurgy, Mechanics, and Materials Science,.
R: Senior or graduate student Engineering, Natural Science, Natural Resources Chemical Engineering Materials Science, Chemistry, Packaging
Physical and chemical nature of solid surfaces and their interaction with gases, liquids, and other solids; characterization of surfaces and solid-solid interfaces; and relation of surface and interfacial structure to engineering phenomena.

999**.** ***Doctoral Dissertation Research
Fall, Spring, Summer. 1 to 12 credits. May reenroll for a maximum of 48 credits.
R: Open only to graduate students in Chemical Engineering.

QA: CHE 999

CHEMISTRY CEM

141. ***General Chemistry***
Fall, Spring. 4(4-0)
P: MTH 110 or MTH 116 or concurrently. R: Not open to students with credit in CEM 151.
Atoms, molecules, ions; chemical calculations; reactions, energy changes; gases; periodic properties of elements; chemical bonds; states of matter, solutions; acids and bases; aqueous reactions and ionic equations.

142. ***General and Inorganic Chemistry***
Fall, Spring. 3(3-0)
P: CEM 141 or CEM 151. R: Not open to students with credit in CEM 152.
Kinetics; gaseous equilibria; acids and bases; pH; aqueous equilibria involving buffers, hydrolysis, and titrations; heterogeneous equilibria of weakly soluble salts; electrochemistry; coordination chemistry, stereochemistry, and bonding within the trans

143. ***Survey of Organic Chemistry***
Fall, Spring. 4(3-3)
P: CEM 141 or CEM 151. R: Not open to students with credit in CEM 251 or CEM 351.
Chemistry of carbon compounds. Chemistry of the main organic functional groups with applications to everyday life, industry and biology.

151. ***Principles of Chemistry I***
Fall. 4(4-0)
P: MTH 116 or concurrently. R: Not open to students with credit in CEM 141.
Atomic and molecular structure; ionic solids; molecular and solid state bonding models; periodic trends; chemical reactivity of the elements by periodic groups; nomenclature, bonding, and reaction chemistry of the transition elements; special topics in b

152. ***Principles of Chemistry II***
Spring. 3(3-0)
P: CEM 141 or CEM 151. R: Not open to students with credit in CEM 142.
Chemical calculations, stoichiometry and reactions; pure phases and solutions; thermodynamics, enthalphy, entropy and free energy; chemical equilibria, aqueous, acid/base and electrochemical (half-cells); chemical kinetics; introduction to quantum theory

161. ***Chemistry Laboratory I***
Fall, Spring. 1(0-3)
P: CEM 141 or CEM 151 or concurrently.
Quantitative physiochemical or analytical experiments and chemical synthesis.

162. ***Chemistry Laboratory II***
Spring. 1(0-3)
P: CEM 161; CEM 142 or CEM 152 or concurrently.
Preparation and qualitative analysis of inorganic compounds.

181H**.** ***Honors Chemistry I
Fall. 4(4-0)
P: MTH 124 or MTH 132 or MTH 152H or concurrently. R: Designated score on Chemistry placement test. Not open to students with credit in CEM 141 or CEM 151.
Subatomic, atomic & molecular structure. Quantum theory and bonding. Stereochemistry & nomenclature. Experimental methods of structure determination. Reactions of compounds of the main-group & transition elements. Reaction dynamics. Nuclear chemistry.

QP: MTH 112 ORMTH 122 QA: CEM 181H CEM 182H

182H**.** ***Honors Chemistry II
Spring. 4(4-0)
P: CEM 181H; MTH 126 or MTH 133 or MTH 153H or concurrently. R: Not open to students with credit in CEM 142 or CEM 152.
States of matter. Descriptive inorganic chemistry by periodic groups of elements. Kinetic theory of gases. Thermodynamics, chemical equilibrium & electrochemistry. Properties of solutions. Macromolecular chemistry. Macroscopic kinetics.
QP: CEM 181HMTH 113 QA: CEM 182H CEM 183H

CHEMISTRY

185H*. ***Honors Chemistry Laboratory I***
Fall. 2(0-6)
C: CEM 181H
Techniques of measurement: experiments related to gas behavior, thermodynamics, electrochemistry, chemical kinetics and properties of solutions.
QA: CEM 184H CEM 185H

186H*. ***Honors Chemistry Laboratory II***
Spring. 2(0-6)
R: Approval of department.
Introductory independent laboratory work in chemistry.
QA: CEM 186H

251. ***Organic Chemistry I***
Fall, Spring. 3(4-0)
P: CEM 142 or CEM 152 or CEM 181H. R: Not open to students with credit in CEM 143 or CEM 351.
Common classes of organic compounds including their nomenclature, structure, bonding, reactivity, and spectroscopic characterization.

252. ***Organic Chemistry II***
Fall, Spring. 3(4-0)
P: CEM 251. R: Not open to students with credit in CEM 352.
Continuation of 251 with emphasis on polyfunctional compounds, particularly those of biological interest.

255. ***Organic Chemistry Laboratory***
Fall, Spring. 2(1-3)
P: CEM 252 or concurrently. R: Not open to students with credit in CEM 353.
Preparation and qualitative analysis of organic compounds.

262. ***Quantitative Analysis***
Fall, Spring. 2(1-3)
P: CEM 162.
Preparation and quantitative analysis of chemical compounds.

333*. ***Instrumental Methods***
Spring. 3(1-6)
P: CEM 143 or CEM 251 or CEM 351; CEM 262. R: Not open to students with credit in CEM 372.
Principles of instrumental analysis. Application of separation techniques and instrumental analysis.
QP: CEM 143 CEM 241CEM 351CEM 162
QA: CEM 333

351*. ***Organic Chemistry I***
Fall. 3(4- 0)
P: CEM 152 or CEM 182H. R: Not open to students with credit in CEM 143 or CEM 251.
Structure, bonding, and reactivity of organic molecules.
QP: CEM 152 CEM 182H QA: CEM 351 CEM 241 CEM 143

352*. ***Organic Chemistry II***
Spring. 3(4-0)
P: CEM 351. R: Not open to students with credit in CEM 252.
Carboxylate derivatives. Conjugation. Aromaticity. Amino acids. Proteins. Carbohydrates. Nucleic acids.
QP: CEM 351 QA: CEM 352 CEM 353 CEM 242 CEM 245

355*. ***Organic Laboratory I***
Spring. 2(0- 6)
P: CEM 162. C: CEM 352 R: Not open to students with credit in CEM 255.
Organic laboratory techniques. Distillation. Spectroscopy. Melting points. Recrystallization. Chromatography. Measuring physical properties.
QP: CEM 162 CEM 185HCEM 241CEM 351
QA: CEM 243

356*. ***Organic Laboratory II***
Fall. 2(0-6)
P: CEM 355
Multi-step organic synthesis. Qualitative organic analysis. Separation, identification, and characterization of unknowns.
QP: CEM 354 QA: CEM 355 CEM 356 CEM 244

361*. ***Analytical-Physical Chemistry I***
Fall. 3(4-0)
P: CEM 142 or CEM 152 or CEM 182H; MTH 234 or MTH 254H; PHY 182B or PHY 184 or PHY 184B or PHY 232 or PHY 232B or PHY 294H. R: Not open to students with credit in CEM 383.
Thermodynamics and its application to simple systems: gases, liquids and solids.
QP: MTH 215 PHY 239PHY 289CEM 153CEM 142 QA: CEM 361 CEM 362

362*. ***Analytical-Physical Chemistry II***
Spring. 3(4-0)
P: CEM 361.
Advanced treatment of equilibria, chemical kinetics and separations.
QP: CEM 361 QA: CEM 362 CEM 363

372*. ***Analytical-Physical Chemistry Laboratory I***
Spring. 3(1-6)
P: CEM 262; CEM 383 or CEM 361.
Electronic and optical components of chemical instrumentation. Spectroscopic and chromatographic methods.
QP: CEM 162 CEM 383CEM 361 QA: CEM 371 CEM 372

383*. ***Introductory Physical Chemistry I***
Fall. 3(4-0)
P: CEM 143 or CEM 251 or CEM 351; MTH 133 or MTH 153H. R: Not open to students with credit in CEM 361.
Physical chemistry of macroscopic systems: thermodynamics, kinetics, electrochemistry.
QP: CEM 143 CEM 241CEM 351MTH 113
QA: CEM 383 CEM 385

384*. ***Introductory Physical Chemistry II***
Spring. 3(4-0)
P: CEM 383. R: Not open to students with credit in CEM 461.
Physical chemistry of microscopic systems: quantum mechanics, spectroscopy.
QP: CEM 383 QA: CEM 384

400H*. ***Honors Work***
Fall, Spring, Summer. 1 to 12 credits. May reenroll for a maximum of 12 credits.
R: Approval of department.
Readings and investigations in chemistry.
QA: CEM 400H

411*. ***Inorganic Chemistry***
Spring. 4(4-0)
P: CEM 361 or CEM 383.
Principles of structure and bonding, symmetry; solid state chemistry; acid-base and redox reactions. Main group chemistry: transition metal bonding, spectra and reaction mechanisms.
QP: CEM 385 ORCEM 363 QA: CEM 411

415A*. ***Advanced Synthesis Laboratory***
Spring. 1(0-3)
P: CEM 356; CEM 411 or concurrently.
R: Open only to majors in Chemistry.
Synthetic methods in inorganic and organometallic chemistry.
QP: CEM 411

415B*. ***Advanced Synthesis Laboratory***
Spring. 1(0-3)
P: CEM 255; CEM 411 or concurrently.
R: Open only to majors in Chemistry with a teacher certification option.
Synthetic methods in inorganic and organometallic chemistry.
QP: CEM 411

419*. ***Problems and Reports***
Fall, Spring, Summer. 1 to 12 credits. May reenroll for a maximum of 12 credits.
R: Approval of department.
Faculty supervised readings and independent investigations.
QA: CEM 419

430*. ***Introduction to Radioactivity and Radioisotope Techniques***
Spring. 3(2-3)
P: CEM 142, PHY 232.
Elementary nuclear processes and properties. Radioactivity, its measurement and its interaction with matter.
QP: CEM 142 PHY 239 QA: CEM 430

461*. ***Theoretical Chemistry***
Fall. 3(4-0)
P: CEM 361 or CEM 383 or concurrently; MTH 234.
Postulates of quantum mechanics. Model problems. Theories of chemical bonding. Interaction of radiation with matter. Foundation of spectroscopy, statistical mechanics.
QP: MTH 215 CEM 362 QA: CEM 461 CEM 462

472*. ***Analytical-Physical Chemistry Laboratory II***
Fall. 3(1-6)
P: CEM 372; CEM 461 or CEM 384 or concurrently.
Kinetic measurements. Electrochemical, radiochemical and spectrophotometric measurements of reaction rates. Mass spectrometry. Electronic, vibrational and rotational spectroscopy.
QP: CEM 363 CEM 373 QA: CEM 471 CEM 472

499*. ***Chemical Physics Seminar***
Fall, Spring, Summer. 1(1-0) May reenroll for a maximum of 2 credits.
P: CEM 362, MTH 235, PHY 321.
Written and oral reports on selected journal articles in chemical physics.
QP: MTH 215 PHY 428 QA: CEM 499

811*. ***Advanced Inorganic Chemistry I***
Fall. 3(3-0)

Physical inorganic chemistry emphasizing the principles of chemical bonding, electronic structure, and reaction mechanisms of main group and transition metalcompounds. Concepts of group theory in inorganic chemistry
QA: CEM 810 CEM 811 CEM 813

812*. ***Advanced Inorganic Chemistry II***
Spring. 3(3-0)

Continuation of CEM 811. Descriptive chemistry of inorganic compounds. Emphasis on synthesis, structure, and reactivity patterns of coordination, organometallic, and solid state compounds of transition metals and main group elements
QA: CEM 810 CEM 811 CEM 813

832*. ***Mass Spectrometry***
Fall of odd-numbered years. 3(3-0)

Introduction to the instrumentation of mass spectrometry. Strategies for inter-preting mass spectra of organic and inorganic molecules. Applications of mass spectrometry for the analysis of large molecules. Mass spectrometers in chrom- atography

834*. ***Advanced Analytical Chemistry***
Fall. 3(3-0)

Principles of equilibria and applications in analytical methodology. Acid-base,complexation, redox reactions. Potentiometry and conductometry. Solute partitioning in extraction and chromatography. Kinetic methods of analysis.
QA: CEM 834

835*. ***Spectrochemical Methods of Analysis***
Spring of even-numbered years. 3(2-3)

Principles and applications of atomic absorption, emission, fluorescence; plasma emission spectroscopy; UV, visible, IR spectrophotometry; reaction-rate methods; molecular fluorescence and phosphorescence; principles and applicationsof lasers
QA: CEM 835

836*. ***Separation Science***
Spring of odd-numbered years. 3(3-0)

Physical and chemical principles of separations, column technology, and instrumentation for gas, liquid, and supercritical fluid chromatography
QA: CEM 836

837*. ***Electroanalytical Chemistry***
Fall of even-numbered years. 3(3-0)

Modern electroanalytical chemistry. Theory and applications to chemical and logical problems. Coulometry, voltammetry, electrometric titations, and ion- selective potentiometry in macro, micro, and trace analysis
QA: CEM 837

838*. ***Computer-Based Instrumentation***
Fall. 3(2-6) May reenroll for a maximum of 12 credits.

Principles of analog and digital devices and systems. Computer applications in scientific measurement and control. Operational amplifiers, digital logic devi-ces, analog to digital converters, counters, and their applications in instru- mentation
QA: CEM 838

845*. ***Structure and Spectroscopy of Organic Compounds***
Fall. 3(3-0)

Structural and stereochemical principles in organic chemistry. Applications of spectroscopic methods, especially nuclear magnetic resonance, to elucidate static and dynamic aspects of stereochemistry. Use of spectroscopy in structuredetermination
QA: CEM 844

851*. ***Advanced Organic Chemistry***
Fall. 3(3-0)

Structure, reactivity, and methods in organic chemistry. Acid-base reactions, substitution, addition, elimination, and pericyclic processes. Major organic intermediates, discussed in the context of simple bonding theory, kinetics, and thermodynamics
QA: CEM 860 CEM 861

852*. ***Methods of Organic Synthesis***
Spring. 3(3-0)

In-depth coverage of the principal reactions leading to carbon-carbon bond formation, along with functional group transformations. Strategies and methods of organic synthesis
QA: CEM 861 CEM 862

881*. ***Atomic and Molecular Structure***
Fall. 3(3-0)

Postulates of quantum mechanics, analytical solutions of the Schrodinger equation, theoretical descriptions of chemical bonding, introduction to spectroscopy, statistical mechanics, and statistical thermodynamics
QA: CEM 880

882*. ***Kinetics and Spectroscopic Methods***
Spring. 3(3-0)

Rates and mechanisms of chemical reactions, reaction rate theory, kinetic theory of gases, photochemistry, spectroscopic methods, and applications of spectroscopy in elucidating reaction kinetics
QA: CEM 883

883*. ***Computational Quantum Chemistry***
Fall. 3(2-3)
P: CEM 461 or CEM 880 or equivalent
Methods and applications of computational methods in determining electronic energy levels, equilibrium nuclear configurations, and other molecular properties
QP: CEM 461 CEM 880 QA: CEM 880

890*. ***Graduate Problems and Reports***
Fall, Spring, Summer. 1 to 6 credits. May reenroll for a maximum of 12 credits.

Problem-solving and preparation of reports on chemical topics; work at the graduate level in chemistry
QA: CEM 890

899*. ***Master's Thesis Research***
Fall, Spring, Summer. 1 to 20 credits. May reenroll for a maximum of 99 credits.
R: Graduate students Natural science Chemistry
Research in analytical, inorganic, organic, or physical chemistry
QA: CEM 899

913*. ***Selected Topics in Inorganic Chemistry***
Fall, Spring. 1 to 3 credits. May reenroll for a maximum of 9 credits.

Current topics in chemistry of metal-metal bonds and clusters; organometallic chemistry; layered oxides and complex layered oxides; photochemistry; current topics in solid state chemistry; applications of quantum mechanics to inorganic chemistry
QA: CEM 913

924*. ***Selected Topics in Analytical Chemistry***
Fall, Spring. 2 to 3 credits. May reenroll for a maximum of 9 credits.

Topics such as advanced computer techniques, surface chemistry, analytical chemistry of polymers, or statistics for chemists
QA: CEM 924

938*. ***Seminar in Analytical Chemistry***
Fall, Spring. 1(1-0) May reenroll for a maximum of 3 credits.
R: Graduate students Natural Science Chemistry
Discussions of recent advances in analytical chemistry, and reports by graduate students, faculty, and guest lecturers
QA: CEM 938

956*. ***Selected Topics in Organic Chemistry***
Fall, Spring. 1 to 3 credits. May reenroll for a maximum of 12 credits.

Topics such as heterocyclic chemistry, organometallic chemistry, natural products, photochemistry, free radicals, or reaction mechanisms
QA: CEM 956

958*. ***Seminar in Organic Chemistry***
Fall, Spring. 1(1-0) May reenroll for a maximum of 2 credits.
R: Graduate students Natural Science Chemistry
Discussions of recent advances in organic chemistry and reports by graduate students on research
QA: CEM 958

987*. ***Selected Topics in Physical Chemistry I***
Fall. 1 to 3 credits. May reenroll for a maximum of 9 credits.

Topics such as kinetics and photochemistry, macromolecular and surface chemistry, molecular spectroscopy, electric and magnetic properties of matter, or applications of statistical mechanics to chemical problems
QA: CEM 987

988*. ***Selected Topics in Physical Chemistry II***
Spring. 1 to 3 credits. May reenroll for a maximum of 9 credits.

Topics such as analysis and interpretation of molecular spectra, advanced molecular structure theory, magnetic resonance, X-rays and crystal structure, scientific analysis of vacuum systems, or problems in statistical mechanics
QA: CEM 988

992*. ***Quantum Chemistry and Statistical Thermodynamics II***
Spring. 3(3-0)
P: CEM 991 or equivalent
Mathematical background for quantum chemistry and statistical thermodynamics. Analytical and numerical methods of solving quantum chemical problems. Stat- istical mechanics of solids and liquids.
QA: CEM 987 CEM 991 CEM 985

993*. ***Advanced Quantum Chemistry***
Spring of odd-numbered years. 3(3-0) May reenroll for a maximum of 9 credits.

Spectroscopic theory, properties of atoms and molecules in electric and magneticfields, intermolecular forces, many-body theory in quantum chemistry, theories of molecular electronic structure, solid state chemistry, and molecular reactiondynamics
QA: CEM 991

994*. ***Advanced Statistical Mechanics***
Spring of even-numbered years. 3(3-0) May reenroll for a maximum of 9 credits.

Nonequilibrium statistical mechanics and thermodynamics. Correlation functions and spectroscopy, light scattering, magnetic relaxation, transport properties of fluids and gases, and statistical mechanics of chemical reactions

999*. ***Doctoral Dissertation Research***
Fall, Spring, Summer. 1 to 20 credits. May reenroll for a maximum of 99 credits.
R: Graduate students Natural Science Chemistry
Research in analytical, organic, inorganic, and physical chemistry
QA: CEM 999

Courses with an asterisk (*) have not been approved by the University Committee on Curriculum.