316 Unit Operations Laboratory
Spring. 3(1-6) P:M: (CHE 311 and CHE 312 or concurrently and CHE 321 or concurrently and CHE 431 or concurrently) and completion of Tier I writing requirement. R: Open only to students in the Department of Chemical Engineering.
Momentum, heat, and mass transfer. Separation processes: distillation, filtration, and drying. Reactor kinetics. Automatic process control. Laboratory problems requiring team effort.

321 Thermodynamics for Chemical Engineering
Spring. 4(5-0) P:M: (CHE 201)
First and second laws. Thermodynamics of flow and energy conversion processes. Properties of single and multi-component systems. Phase equilibria. Chemical equilibria in reacting systems.

422 Transport Phenomena
Spring. 3(3-0) P:M: (CHE 311 and CHE 312)
Mathematical and physical analogies among mass, energy and momentum transfer processes. Dimensional analysis and solutions to multivariable boundary value problems. Numerical solutions to nonlinear problems.

431 Chemical Reaction Engineering
Spring. 3(3-0) P:M: (CHE 311 and CHE 312 or concurrently and CHE 321 or concurrently) R: Open only to juniors or seniors in the Chemical Engineering major.
Design and analysis of homogeneous flow and batch reactors. Chemical kinetics and equilibria. Reaction rate expressions from mechanisms and experimental data. Mass and heat transfer in heterogeneous reactors. Heterogeneous reactor design. Catalysis.

432 Process Dynamics and Control
Fall. 3(3-0) P:M: (CHE 431)
Mathematical modeling of process dynamics. Control theory. Design of control systems and specification of control hardware. Integration of control theory with modern practice.

433 Process Design and Optimization I
Fall. 4(5-0) P:M: (CHE 432 or concurrently) and completion of Tier I writing requirement. R: Open only to students in the Department of Chemical Engineering.
Applications of chemical engineering principles in design calculations. Selection of optimum design. Influence of design on capital investment, operating cost, product loss and quality. Mathematical programming methods for optimization.

434 Process Design and Optimization II
Spring. 2(0-4) P:M: (CHE 433)
Design project requiring an integrated design of chemical engineering processes. Process and project engineering. Instrumentation and control systems. Flowsheet layout and optimization. Process simulation.

472 Composite Materials Processing
Fall. 3(2-3) P:M: (CHE 311 or ME 332 or CE 321)
Manufacturing processes for thermoset and thermoplastic matrix composites. Mechanical and thermal evaluation of composites. Rheology and molding of fiber-filled materials.

473 Chemical Engineering Principles in Polymers and Materials Systems
Spring. 3(3-0) P:M: (CHE 311 and CHE 321 and CHE 431 and CEM 352) SA: CHE 371
Application of chemical engineering principles to polymer and materials systems. Structures and properties of metals, ceramics and polymers. Thermodynamics,synthesis, rubber elasticity, viscoelasticity, kinetics, rheology, and processing of polymers systems. Application of statistics and problem-solving skills to materials systems.

481 Biochemical Engineering
Fall. 3(2-3) P:M: (CHE 431)
Applications of microbiology and biochemistry to biochemical engineering. Kinetics and thermodynamics of biochemical reactors. Transport phenomena in biological systems. Bioreactor design and scale-up.

490 Independent Study
Fall, Spring, Summer. 1 to 3 credits. A student may earn a maximum of 6 credits in all enrollments for this course. R: Open only to juniors or seniors or graduate students in the Department of Chemical Engineering. Approval of department.
Theoretical or experimental studies of current research topics in chemical engineering. Individual interaction with faculty adviser.

491 Selected Topics in Chemical Engineering
Fall, Spring. 1 to 3 credits. A student may earn a maximum of 6 credits in all enrollments for this course. R: Open only to juniors or seniors or graduate students in the Department of Chemical Engineering.
Study of newly developing or non-traditional chemical engineering topics in a classroom environment.

CHEMISTRY CEM

Department of Chemistry
College of Natural Science

141 General Chemistry
Fall, Spring. 4(4-0) P:M: (MTH 103 or concurrently or MTH 110 or concurrently or MTH 116 or concurrently or MTH 124 or concurrently or MTH 132 or concurrently or MTH 152H or concurrently or LBS 117 or concurrently or LBS 118 or concurrently) or designated score on Mathematics placement test. Not open to students with credit in CEM 151 or CEM 181H or LBS 171.
Elements and compounds; reactions; stoichiometry; thermochemistry; atomic structure; chemical bonding; states of matter; solutions; acids and bases; aqueous equilibria.

142 General and Inorganic Chemistry
Fall, Spring. 3(4-0) P:M: (CEM 141 or CEM 151 or CEM 181H or LBS 171) Not open to students with credit in CEM 152 or CEM 182H or LBS 172.
Kinetics; gaseous equilibria; acids and bases; pH; buffers; hydrolysis; titrations; heterogeneous equilibria; thermodynamics; redox and electrochemistry; transition metal chemistry; nuclear chemistry; main group chemistry.

143 Survey of Organic Chemistry
Fall, Spring. 4(3-3) P:M: (CEM 141 or CEM 151) 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 General and Descriptive Chemistry
Fall. 4(4-0) P:M: (MTH 116 or concurrently or MTH 124 or concurrently or MTH 132 or concurrently or MTH 152H or concurrently or LBS 117 or concurrently or LBS 118 or concurrently) or designated score on Mathematics placement test. Not open to students with credit in CEM 141 or CEM 181H or LBS 171.
Atomic structure, chemical bonding and molecular structure; solid state; main group chemistry; acids and bases; transition metal chemistry; coordination chemistry and theories of bonding.

152 Principles of Chemistry
Spring. 3(4-0) P:M: (CEM 151 or CEM 181H or LBS 171) Not open to students with credit in CEM 142 or CEM 182H or LBS 172.
The mole concept and stoichiometry; solution stoichiometry; thermochemistry; gases, liquids, and solids; kinetics; chemical equilibria; acid-based equilibria; aqueous equilibria; thermodynamics; redox and electrochemistry.

161 Chemistry Laboratory I
Fall, Spring. 1(0-3) P:M: (CEM 141 or concurrently or CEM 151 or concurrently) Not open to students with credit in LBS 171L or CEM 185H.
Experiments in general chemistry; stoichiometry, calorimetry, electrochemistry, molecular geometry, gas laws, kinetics, acids and bases, and inorganic chemistry.

162 Chemistry Laboratory II
Fall, Spring. 1(0-3) RB: (CEM 161 or LBS 171L or CEM 185H) and (CEM 142 or concurrently and CEM 152 or concurrently) Not open to students with credit in LBS 172L or CEM 186H.
Analytical and inorganic chemistry; redox and acid base titrations; spectrophotometric and gravimetric analysis; preparation and analysis of coordination complexes of nickel, iron, and cobalt.

181H Honors Chemistry I
Fall. 4(4-0) P:M: (MTH 124 or concurrently or MTH 132 or concurrently or MTH 152H or concurrently or LBS 118 or concurrently) R: Approval of department.
Elements and compounds; stoichiometry; reactions; atomic structure and quantum mechanics, chemical bonding and molecular structure; spectroscopy; coordination chemistry and theories of bonding; structure of biochemical molecules.

182H Honors Chemistry II
Spring. 4(4-0) P:M: (CEM 151 or CEM 181H or LBS 171) and (MTH 126 or concurrently or MTH 133 or concurrently or MTH 153H or concurrently) R: Approval of department.
Thermodynamics and chemical equilibria; acids and bases; redox chemistry; main group elements; solid state; group theory and symmetry; molecular orbital theory; transition metal chemistry and spectroscopy.

185H Honors Chemistry Laboratory I
Fall. 2(0-6) P:M: (CEM 181H or concurrently) R: Approval of department.
Spectroscopy and diffraction methods for the study of electronic structure and molecular geometry; synthesis and separation methods for the preparation and characterization of molecules; application to inorganic, organic, and biochemical molecules and materials.

186H Honors Chemistry Laboratory II
Spring. 2(0-6) P:M: (CEM 182H or concurrently) R: Approval of department.
Laboratory research.

251 Organic Chemistry I
Fall, Spring. 3(4-0) P:M: (CEM 141 or CEM 152 or CEM 182H or LBS 171) 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:M: (CEM 251) Not open to students with credit in CEM 352.
Continuation of CEM 251 with emphasis on polyfunctional compounds, particularly those of biological interest.

255 Organic Chemistry Laboratory
Fall, Spring. 2(1-3) P:M: (CEM 252 or concurrently) and (CEM 161 or LBS 171L or CEM 185H) Not open to students with credit in CEM 355.
Preparation and qualitative analysis of organic compounds.

262 Quantitative Analysis
Fall, Spring, Summer. 3(3-3) P:M: (CEM 162 or LBS 172L) Not open to students with credit in CEM 186H.
Preparation and quantitative analysis of chemical compounds.

333 Instrumental Methods
Spring. 3(2-3) P:M: (CEM 143 or CEM 251 or CEM 351) and (CEM 262 or CEM 186H) and completion of Tier I writing requirement.
Principles of instrumental analysis. Application of separation techniques and instrumental analysis.

351 Organic Chemistry I
Fall. 3(4-0) P:M: (CEM 152 or CEM 182H or CEM 142 or LBS 172) Not open to students with credit in CEM 143 or CEM 251.
Structure, bonding, and reactivity of organic molecules.

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

355 Organic Laboratory I
Spring. 2(0-6) P:M: (CEM 162 or CEM 186H or LBS 172L or CEM 352 or concurrently) and completion of Tier I writing requirement. Not open to students with credit in CEM 255.
Organic laboratory techniques. Distillation. Spectroscopy. Melting points. Recrystallization. Chromatography. Measuring physical properties.

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

383 Introductory Physical Chemistry I
Fall. 3(4-0) P:M: (CEM 142 or CEM 152 or CEM 182H or LBS 172) and (MTH 133 or MTH 153H or MTH 126 or LBS 119) Not open to students with credit in CEM 391.
Physical chemistry of macroscopic systems: thermodynamics, kinetics, electrochemistry.

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

391 Molecular Thermodynamics
Fall. 3(4-0) P:M: (CEM 142 or CEM 152 or CEM 182H) and (MTH 234 or MTH 254H or LBS 220) and (PHY 184 or PHY 232) RB: One year of general chemistry, calculus, and general physics. SA: CEM 361 Not open to students with credit in CEM 383.
Statistical mechanics and its use in classical chemical thermodynamics. Applications of thermodynamics to chemical systems at equilibrium. Introduction to chemical kinetics.

392 Quantum Chemistry
Fall, Spring. 3(4-0) P:M: (CEM 391) and (MTH 234 or LBS 220 or MTH 254H) RB: One year of general chemistry, calculus through differential equations, and general physics. SA: CEM 362, CEM 461 Not open to students with credit in CEM 384.
Postulates of quantum mechanics and their application to model systems, atoms and molecules. Introduction to molecular spectroscopy.

395 Analytical/Physical Laboratory
Spring. 2(1-4) P:M: (CEM 391 or CEM 383) and (CEM 262) and completion of Tier I writing requirement. RB: One year of general chemistry, calculus, and general physics. SA: CEM 372, CEM 472
Chemical kinetics, thermodynamics, and computer-based data analysis methods.

400H Honors Work
Fall, Spring, Summer. 1 to 12 credits. A student may earn a maximum of 12 credits in all enrollments for this course. P:M: Completion of Tier I writing requirement. R: Approval of department.
Readings and investigations in chemistry.

410 Literature and Writing in Chemistry
Spring. 3 credits. P:M: (CEM 252) and (CEM 384) and (CEM 333 or concurrently) and completion of Tier I writing requirement. R: Open only to juniors or seniors in the B.A. degree program in Chemistry.
Library research related to a topic in contemporary chemistry; thesis required.

411 Inorganic Chemistry
Spring. 4(4-0) P:M: (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.

415 Advanced Synthesis Laboratory
Fall. 3(0-8) P:M: (CEM 411) and completion of Tier I writing requirement. R: Open only to juniors or seniors in the B.S. degree program in Chemistry.
Methods of synthesizing inorganic and organometallic compounds.

419 Independent Study
Fall, Spring, Summer. 1 to 12 credits. A student may earn a maximum of 12 credits in all enrollments for this course. R: Approval of department.
Faculty supervised readings in chemistry.

420 Independent Research
Fall, Spring, Summer. 1 to 12 credits. A student may earn a maximum of 12 credits in all enrollments for this course. R: Approval of department.
Faculty supervised independent investigations in chemistry.

434 Advanced Analytical Chemistry
Fall. 3(3-0) P:M: (CEM 392 and CEM 395 and CEM 352) SA: CEM 361, CEM 362
Instrumental methods of analysis, including spectroscopy, chromatography and electrochemistry.

435 Analytical Chemistry Laboratory
Spring. 2(1-3) P:M: (CEM 434 or concurrently) and completion of Tier I writing requirement. SA: CEM 372, CEM 472
Electronic and optical components of chemical instrumentation. Spectroscopic and chromatographic methods.

444 Chemical Safety
Fall. 1(1-0) P:M: (CEM 142 and CEM 252)
Prudent laboratory practices. Regulatory agencies' expectations of chemical industries and academia.

481 Seminar in Computational Chemistry
Fall, Spring, Summer. 1 to 6 credits. A student may earn a maximum of 6 credits in all enrollments for this course. P:M: (MTH 133 and CSE 231) and (CEM 152 or concurrently or CEM 182H or concurrently) RB: (CPS 260 and CEM 351)
Written and oral reports on selected journal articles in computational chemistry.

485 Modern Nuclear Chemistry
Spring of even years. 3(3-0) P:M: (CEM 141 or CEM 152 or CEM 182H) and (PHY 232 or PHY 184) RB: (CEM 392 or CEM 384 or PHY 471) SA: CEM 430
Elementary nuclear processes and properties; radioactivity, its measurement and its interaction with matter.

495 Molecular Spectroscopy
Fall. 2(1-4) P:M: (CEM 392 and CEM 395) RB: One year of physical chemistry. SA: CEM 472
Experiments in magnetic resonance, optical, and vibrational spectroscopies.

499 Chemical Physics Seminar
Fall, Spring, Summer. 1(1-0) A student may earn a maximum of 2 credits in all enrollments for this course. P:M: (PHY 321) and (MTH 235 or LBS 220 or MTH 255H) and completion of Tier I writing requirement.
Written and oral reports on selected journal articles in chemical physics.