

# CHEMISTRY (CHEM)

## Courses

### CHEM 1011 (3) Environmental Chemistry 1

Introduces basic principles of chemistry with applications to current environmental issues including toxic chemicals, air and water pollution, energy sources and their environmental impact, and climate change resulting from the greenhouse effect. No credit given to chemistry or biochemistry majors for this course if students already have credit in any college-level chemistry course numbered 1113/1114 or higher.

**Additional Information:** GT Pathways: GT-SC2 -Natural Physicl Sci:Lec Crse w/o Req Lab

Arts Sci Core Curr: Natural Science Sequence

Arts Sci Core Curr: Natural Science Non-Sequence

Arts Sci Gen Ed: Distribution-Natural Sciences

MAPS Course: Chemistry

MAPS Course: Natural Science

MAPS Course: Physics

### CHEM 1021 (4) Introductory Chemistry

For students with no high school chemistry or a very weak chemistry background. Remedies a deficiency in natural science MAPS requirements and prepares students for CHEM 1113 and CHEM 1114 or CHEM 1400 and CHEM 1401. No credit given to chemistry or biochemistry majors for this course if students already have credit in any college-level chemistry course numbered 1113/1114 or higher.

Department enforced prerequisite: one year high school algebra or concurrent enrollment in MATH 1011.

**Additional Information:** GT Pathways: GT-SC1 - Natural Physcal Sci:Lec Crse w/ Req Lab

Arts Sci Core Curr: Natural Science Non-Sequence

Arts Sci Core Curr: Natural Science Lab

Arts Sci Gen Ed: Distribution-Natural Sci Lab

Arts Sci Gen Ed: Distribution-Natural Sciences

MAPS Course: Natural Science Lab or Lab/Lec

### CHEM 1031 (4) Environmental Chemistry 2

Applications of chemical principles to current environmental issues including acid rain, stratospheric ozone depletion, the Antarctic ozone hole, solar energy conversion and fuel cells, and the environmental consequences of nuclear war. Laboratory experience is included. No credit given to chemistry or biochemistry majors this course if students already have credit in any college-level chemistry course numbered 1113/1114 or higher.

**Requisites:** Requires prerequisite course of CHEM 1011 (minimum grade C-).

**Additional Information:** Arts Sci Core Curr: Natural Science Sequence

Arts Sci Core Curr: Natural Science Lab

Arts Sci Gen Ed: Distribution-Natural Sci Lab

Arts Sci Gen Ed: Distribution-Natural Sciences

### CHEM 1113 (4) General Chemistry 1

Intended for first-semester students whose academic plans require advanced work in chemistry. Subjects: components of matter, stoichiometry, classes of reactions, gases, thermochemistry, atomic structure, electron configuration, chemical bonding, molecular shapes, covalent bonding, organic compounds, intermolecular forces, equilibrium. Department enforced prerequisites: one year high school chemistry or CHEM 1021 (min grade C-); high school math through pre-calculus. Not recommended for students with grades below B- in CHEM 1021. Department enforced corequisite: CHEM 1114. Not open to engineering students with exception of EPEN majors.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 1400 or CHEN 1211

**Requisites:** AMEN, AREN, ASEN, CHEN, CSEN, CVEN, ECEN, EEEN, EVEN, MCEN, OPEN or CBEN majors are not allowed to take this class.

**Additional Information:** GT Pathways: GT-SC2 -Natural Physicl Sci:Lec Crse w/o Req Lab

Arts Sci Core Curr: Natural Science Sequence

Arts Sci Gen Ed: Distribution-Natural Sciences

### CHEM 1114 (1) Laboratory in General Chemistry 1

Lab. Intended for first-semester students whose academic plans require advanced work in chemistry. Instruction in experimental techniques which coordinate with lecture topics in CHEM 1113. Department enforced prerequisites: one year high school chemistry or CHEM 1021 (min grade C-); high school math through pre-calculus. Not recommended for students with grades below B- in CHEM 1021. Department enforced corequisites: CHEM 1113 or CHEN 1201.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 1401 or CHEM 1221

**Requisites:** ASEN, ECEN, EEEN, EVEN, and MCEN majors may not enroll in this course.

**Additional Information:** GT Pathways: GT-SC1 - Natural Physcal Sci:Lec Crse w/ Req Lab

Arts Sci Core Curr: Natural Science Lab

Arts Sci Gen Ed: Distribution-Natural Sci Lab

Arts Sci Gen Ed: Distribution-Natural Sciences

### CHEM 1133 (4) General Chemistry 2

Intended for second-semester students whose academic plans require advanced work in chemistry. Subjects: acid-base equilibria, buffers and titrations, thermodynamics, redox reactions, electrochemistry, transition elements and their coordination compounds, solubility/solubility equilibria, crystal field theory, kinetics, nuclear chemistry. Department enforced corequisite: CHEM 1134.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 2100

**Requisites:** Requires prerequisite courses of CHEM 1113 and CHEM 1114 or CHEM 1400 and CHEM 1401 or CHEN 1211 and CHEM 1221 or CHEN 1201 and CHEM 1114 or CHEN 1203 and CHEM 1221 (all minimum grade C-).

**Additional Information:** GT Pathways: GT-SC2 -Natural Physicl Sci:Lec Crse w/o Req Lab

Arts Sci Core Curr: Natural Science Sequence

Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 1134 (1) Laboratory in General Chemistry 2**

Intended for second-semester students whose academic plans require advanced work in chemistry. Instruction in experimental techniques which coordinate with lecture topics in CHEM 1133. Department enforced corequisite: CHEM 1133.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 2101

**Requisites:** Requires prerequisite courses of CHEM 1113 and CHEM 1114 or CHEM 1400 and CHEM 1401 or CHEN 1211 and CHEM 1221 or CHEN 1201 and CHEM 1114 or CHEN 1203 and CHEM 1221 (all minimum grade C-).

**Additional Information:** GT Pathways: GT-SC1 - Natural Physical Sci:Lec Crse w/ Req Lab

Arts Sci Core Curr: Natural Science Lab

Arts Sci Gen Ed: Distribution-Natural Sci Lab

Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 1221 (1) Engineering General Chemistry Lab**

Meets general chemistry laboratory requirement for engineering students. Designed to illustrate chemical concepts and introduce basic techniques in chemical measurement and synthesis. Department enforced prerequisites: one year of high school chemistry or CHEM 1021 (min. grade C-) and high school algebra; B- in CHEM 1021 recommended.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 1114 or CHEM 1401

**Requisites:** Requires prerequisite course of CHEN 1211 or CHEM 1133 (minimum grade C-), or corequisite course of CHEN 1211 or CHEM 1133. Restricted to undergraduate engineering students and IUT On Track applicants.

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sci Lab

Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 1400 (4) Foundations of Chemistry**

Covers core concepts in chemistry: nature of matter (atomic and molecular structure, bonding and macroscopic properties), transformations of matter (chemical reactivity), and quantifying chemical transformations (thermochemistry, thermodynamics and kinetics). Emphasizes critical thinking and cultivate core problem solving skills utilized by scientists. Intended for first semester CHEM/BCHM majors. Department enforced prerequisites: one year high school chemistry or CHEM 1021 (minimum grade C-) and high school math through pre-calculus. Not recommended for students with grades below B- in CHEM 1021. Department enforced corequisite: CHEM 1401.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 1113

**Requisites:** Restricted to Chemistry (CHEM) or Biochemistry (BCHM) majors only.

**Grading Basis:** Letter Grade

**Additional Information:** Arts Sci Core Curr: Natural Science Non-Sequence

Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 1401 (1) Foundations of Chemistry Lab**

Coordinates with lecture topics in CHEM 1400. Intended for first-semester CHEM and BCHM majors. Emphasizes the development of hands-on practical laboratory skills, experimental design, data interpretation, problem solving and open inquiry. Department enforced prerequisites: one year high school chemistry or CHEM 1021 (minimum grade C-) and high school math through pre-calculus. Not recommended for students with grades below B- in CHEM 1021. Department enforced corequisite: CHEM 1400.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 1114 or CHEM 1221

**Requisites:** Restricted to Chemistry (CHEM) or Biochemistry (BCHM) majors only.

**Grading Basis:** Letter Grade

**Additional Information:** Arts Sci Core Curr: Natural Science Lab

Arts Sci Gen Ed: Distribution-Natural Sci Lab

Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 2100 (4) Foundations of Chemistry 2**

Covers the energetic principles that determine when chemical reactions occur and the dynamic principles that determine how rapidly they will occur. Applications include ionic equilibria in solution (acids and bases, buffers and titrations), oxidation-reduction reactions, electrochemistry and chemical kinetics. These applications will be situated in a context of current research problems in areas such as renewable energy and atmospheric chemistry. Department enforced corequisite: CHEM 2101.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 1133

**Requisites:** Requires prerequisite courses of CHEM 1400 and CHEM 1401 (minimum grade C-) or CHEM 1113 and CHEM 1114 (minimum grade B) and prerequisite or corequisite of MATH 2300 or APPM 1360 (minimum grade C-).

**Additional Information:** Arts Sci Core Curr: Natural Science Sequence

Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 2101 (1) Laboratory in Foundations of Chemistry 2**

Coordinates with the lectures topics in CHEM 2100. Emphasizes the acquisition of more advanced laboratory skills, experimental design, data interpretation and analysis. Department enforced corequisite: CHEM 2100.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 1134

**Requisites:** Requires prerequisite courses of CHEM 1400 and CHEM 1401 (minimum grade C-) or CHEM 1113 and CHEM 1114 (minimum grade B) and prerequisite or corequisite of MATH 2300 or APPM 1360 (minimum grade C-).

**Grading Basis:** Letter Grade

**Additional Information:** Arts Sci Core Curr: Natural Science Lab

Arts Sci Gen Ed: Distribution-Natural Sci Lab

Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 3151 (3) Air Chemistry and Pollution**

Examines the composition of the atmosphere, and sources of gaseous and particulate pollutants: their chemistry, transport and removal from the atmosphere. Applies general principles to acid rain, smog and stratospheric ozone depletion. Department enforced prerequisite: two semesters of chemistry.

**Equivalent - Duplicate Degree Credit Not Granted:** ATOC 3500

**Additional Information:** Arts Sci Core Curr: Natural Science Non-Sequence

Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 3251 (3) Sustainable Energy from a Chemistry Perspective**

Explores qualitative and quantitative chemical aspects of energy systems (production, transmission, storage, utilization) including fossil, wind, solar, nuclear and biomass energy. Applies chemical principles including composition, structure, bonding, physical properties, thermodynamics, equilibrium and kinetics to energy systems and sustainability, especially environmental implications. Describes the importance of energy to the chemical industries and society as a whole.

**Requisites:** Requires prerequisite course of CHEM 1133 and 1134 or CHEM 2100 and 2101 or CHEN 1211 and CHEM 1221 (all minimum grade C-).

**CHEM 3311 (4) Organic Chemistry 1**

Intended primarily for nonmajors. Topics include structure and reactions of alkanes, alkenes, alkynes, alkyl halides, and aromatic molecules; nomenclature of organic compounds; stereochemistry; reaction mechanisms and dynamics. Department enforced corequisite: CHEM 3321.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 3451

**Requisites:** Requires prerequisite course of (CHEM 1133 and CHEM 1134) or (CHEM 1400 and CHEM 1401) or (CHEM 2100 and CHEM 2101) or (CHEN 1211 and CHEM 1221) or (CHEN 1203 and CHEM 1221) (all minimum grade C-).

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 3321 (1) Laboratory in Organic Chemistry 1**

Instruction in experimental techniques of modern organic chemistry emphasizing chemical separations and reactions of alkanes, alkenes, and aromatic compounds. Stereochemical modeling and the identification of organic unknowns by spectroscopic and chemical methods are also introduced. Department enforced corequisite: CHEM 3311 or CHEM 3451.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 3361

**Requisites:** Requires prerequisite course of (CHEM 1133 and CHEM 1134) or (CHEM 1400 and CHEM 1401) or (CHEM 2100 and CHEM 2101) or (CHEN 1211 and CHEM 1221) or (CHEN 1203 and CHEM 1221) (all minimum grade C-).

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sci Lab  
Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 3331 (4) Organic Chemistry 2**

Lect. and rec. Intended primarily for nonmajors. Topics include structure and reactions of alkyl halides, alcohols, ethers, carboxylic acids, aldehydes, ketones, and amines; introduction to the chemistry of heterocycles, carbohydrates, and amino acids; nomenclature of organic compounds; synthesis; and reaction mechanisms. Department enforced corequisite: CHEM 3341 or CHEM 3381.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 3471 or BCHM 3491

**Requisites:** Requires prerequisite courses of (CHEM 3311 or CHEM 3451) and CHEM 3321 (all minimum grade C-).

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 3341 (1) Laboratory in Organic Chemistry 2**

Lab. Instruction in experimental techniques of modern organic chemistry emphasizing reactions involving alcohols, ketones, carboxylic acids, and their derivatives. Department enforced corequisite: CHEM 3331 or CHEM 3471 or BCHM 3491.

**Requisites:** Requires prerequisite courses of (CHEM 3311 or CHEM 3451) and CHEM 3321 (all minimum grade C-).

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sci Lab  
Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 3381 (2) Laboratory in Advanced Organic Chemistry**

Lab. Instruction in experimental techniques of modern organic chemistry, emphasizing chemical literature, advanced spectroscopy, and reactions involving organometallic compounds, microwave chemistry, and column chromatography. Multistep syntheses are also introduced, including an independent synthesis project.

**Requisites:** Requires prerequisite courses of (CHEM 3331 or CHEM 3471 or BCHM 3491) and CHEM 3341 (all minimum grade C-). Restricted to Chemistry (CHEM) or Biochemistry (BCHM) majors only.

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sci Lab  
Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 3451 (4) Organic Chemistry 1 for Chemistry and Biochemistry Majors**

Covers bonding, acidity, reaction mechanisms, nomenclature of organic compounds; stereochemistry; structure and reactions of aldehydes, ketones, and carboxylic acids and derivatives. Department enforced corequisite: CHEM 3321.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 3311

**Requisites:** Requires prerequisite courses of (CHEM 1133 and CHEM 1134) or (CHEM 1400 and CHEM 1401) or (CHEM 2100 and CHEM 2101) or (CHEN 1211 and CHEM 1221) or (CHEN 1203 and CHEM 1221) (all min grade C-). Restricted to Chemistry (CHEM) or Biochemistry (BCHM) mjrs

**Grading Basis:** Letter Grade

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 3471 (4) Organic Chemistry 2 for Chemistry Majors**

Covers Amines, alkylation reactions, additions to unsaturated C-C bonds, aromaticity, and aromatic reactivity, organic materials, biomolecules, nomenclature of organic compounds, reaction mechanisms. Department enforced corequisite: CHEM 3341.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 3331 or BCHM 3491

**Requisites:** Requires prerequisite courses of (CHEM 3311 or CHEM 3451) and CHEM 3321 (all minimum grade C-). Restricted to Chemistry (CHEM) or Biochemistry (BCHM) majors only.

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 4011 (3) Modern Inorganic Chemistry**

Required course for chemistry majors. Introduces modern inorganic chemistry for undergraduates. Includes atomic structure, chemical periodicity, structure and bonding in molecules and crystals, reaction mechanisms, chemistry of selected main group and transition elements, and emphasis on catalyst, materials, bioinorganic, and organometallic systems.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 5011

**Requisites:** Requires prerequisite course of CHEM 3331 or CHEM 3471 or CHEM 3491 (minimum grade C-).

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 4021 (3) Inorganic Laboratory**

One lect. and two 3-hour labs per week. Instruction in experimental techniques of modern inorganic chemistry. Includes syntheses and spectroscopic characterizations of transition metal and main group compounds, experience in manipulation of air sensitive compounds, and techniques involving unusual conditions of pressure or temperature.

**Requisites:** Requires prerequisite course of CHEM 4011 (minimum grade C-). Restricted to Chemistry (CHEM) or Biochemistry (BCHM) majors only.

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sci Lab  
Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 4141 (3) Environmental Water and Soil Chemistry**

Application of basic chemical principles to understanding the processes that determine the chemical composition of oceans, lakes, rivers, soils and sediments. Topics include air-water exchange; acid-base, redox, coordination, precipitation and dissolution, ion exchange and sorption reactions; nutrient chemistry; and the use of simple equilibrium and kinetic models for describing the chemistry of inorganic and organic species in air-water-soil systems.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 5141

**Requisites:** Requires prerequisite course of CHEM 2100 and CHEM 2101 or CHEM 1133 and CHEM 1134 (minimum grade C-). Restricted to students with 57-180 credits (Juniors or Seniors).

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 4171 (3) Instrumental Analysis - Lecture and Laboratory 1**

Two Lect. and 3 hours of lab per week. Instruction and experience in using instrumental methods of chemical analysis to address problems in chemistry, biochemistry, industrial chemistry and environmental chemistry.

**Requisites:** Requires prerequisite course of CHEM 3331 or CHEM 3471 or CHEM 3491 and CHEM 3341 or CHEM 3381 and PHYS 1140 or CHEM 4400 or CHEM 4511 (minimum grade C-). Restricted to Chemistry (CHEM) or Biochemistry (BCHM) majors only.

**Grading Basis:** Letter Grade

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sci Lab  
Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 4181 (3) Instrumental Analysis - Lecture and Laboratory 2**

Two lect. and 3 hours of lab per week. Instruction and experience in using instrumental methods of chemical analysis. Builds on material learned in CHEM 4171.

**Requisites:** Requires prerequisite course of CHEM 4171 (minimum grade C-). Restricted to Chemistry (CHEM) or Biochemistry (BCHM) majors only.

**Grading Basis:** Letter Grade

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sci Lab  
Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 4251 (3) Materials Chemistry and Properties**

Lec. Understanding of materials from chemistry perspective including metals, oxides, semiconductors and polymers. Basic description of chemical preparation of materials. Overview of fundamental properties of materials including structural, chemical, mechanical, thermal, electrical, and optical properties. Description of behavior of materials and various applications in modern technology. Discussion of materials characterization methods.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 5251

**Requisites:** Requires prerequisite course of CHEM 3331 or CHEM 3471 or CHEM 3491 and CHEM 4521 or CHEM 4531 (all minimum grade C-).

**CHEM 4261 (3) Organic Materials: Structures and Functions**

Overview of the preparation and functioning mechanism of novel organic materials that have recently been developed, including conductive polymers, 2-D macrocyclic structures, 3-D molecular cages, molecular machines/muscles/switches, fullerene derivatives and carbon nanotube composites. Emphasizes the use of organic and physical chemistry as tools to develop novel materials and probe their structure-property relationship.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 5261

**Requisites:** Requires prerequisite courses of CHEM 3331 or CHEM 3471 or CHEM 3491 and CHEM 4531 (all minimum grade C-).

**CHEM 4271 (3) Chemistry of Solar Energy**

Chemical principles of conversion of solar energy into electricity and fuels in molecular and semiconductor-based systems. Overview of solid-state electronic structure of materials and interfaces, light-matter interactions, principles of harvesting photoexcited currents and useful chemical species. Description of processes utilized in established and emerging solar energy technologies.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 5271

**Requisites:** Requires prerequisite courses of CHEM 3331 or CHEM 3471 or CHEM 3491 and CHEM 4531 (all minimum grade C-).

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 4511 (3) Physical Chemistry 1**

Chemical thermodynamics and kinetics. Includes study of laws of thermodynamics, thermochemistry, entropy, free energy, chemical potential, chemical equilibria, and the rates and mechanisms of chemical reactions. Department enforced prereq or coreq., PHYS 1120 (minimum grade C-).

**Equivalent - Duplicate Degree Credit Not Granted:** BCHM 4400 and BCHM 5400

**Requisites:** Requires prereq courses of CHEM 1133 CHEM 1134 or CHEM 2100 CHEM 2101 or CHEM 1211 CHEM 1221 and MATH 2400 or APPM 2350 and PHYS 1110 or PHYS 1115 or PHYS 2020 (all minimum grade C-). Restricted to Chemistry (CHEM) or Biochemistry (BCHM) majors.

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 4531 (3) Physical Chemistry 2**

Lect. Introduces the quantum theory of atoms, molecules and chemical bonding, and statistical thermodynamics. Includes principles of quantum mechanics and their application to atomic structure, molecular spectroscopy, symmetry properties, and the determination of molecular structure. Also includes principles of statistical mechanics and their applications to properties of gases, liquids, and solids.

**Requisites:** Requires prerequisite courses of CHEM 4511 and PHYS 1120 or PHYS 2020, and MATH 2400 or APPM 2350 (all minimum grade C-). Restricted to Chemistry (CHEM) or Biochemistry (BCHM) majors only.

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 4555 (4) Theoretical and Computational Chemistry**

Explores computational methods to understand chemical systems. Topics include: atomic and molecular electronic structure calculations, Monte Carlo and molecular dynamics simulations and thermodynamic calculations. Not recommended for students with a grade below B- in the prerequisite course.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 5555

**Requisites:** Requires prerequisite course of CHEM 4531 (minimum grade C-).

**Grading Basis:** Letter Grade

**CHEM 4581 (1) Physical Chemistry Lab 1**

One 3-hour lab per week. Instruction in experimental techniques of modern physical chemistry. Experiments illustrate the fundamental principles of thermodynamics and chemical kinetics. Illustrates the material discussed in CHEM 4511.

**Requisites:** Requires prerequisite or corequisite course of CHEM 4511 (minimum grade C-). Restricted to Chemistry (CHEM) or Biochemistry (BCHM) majors only.

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sci Lab  
Arts Sci Gen Ed: Distribution-Natural Sciences



**CHEM 4591 (2) Physical Chemistry Lab 2**

One lect. and one 3-hour laboratory every two weeks. a continuation of CHEM 4581, but may be taken concurrently with CHEM 4531. Experiments illustrate the principles of quantum chemistry and spectroscopy discussed in CHEM 4531.

**Requisites:** Requires prerequisite courses of CHEM 4511 and CHEM 4581 (all minimum grade C-). Requires prerequisite or corequisite course of CHEM 4531 (minimum grade C-). Restricted to Chemistry (CHEM) or Biochemistry (BCHM) majors only.

**Additional Information:** Arts Sci Gen Ed: Distribution-Natural Sci Lab  
Arts Sci Gen Ed: Distribution-Natural Sciences

**CHEM 4901 (1-6) Independent Study in Chemistry**

For undergraduate study. Department consent required. Repeatable up to 8 total credit hours.

**Repeatable:** Repeatable for up to 8.00 total credit hours.

**CHEM 5011 (3) Advanced Inorganic Chemistry 1**

Inorganic chemistry based on principles of bonding, structure, reaction mechanisms, and modern synthetic methods. Chemistry and general properties of representative and transition elements and their compounds.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 4011

**Requisites:** Requires prerequisite courses of CHEM 4011 and CHEM 4531 (all minimum grade B-) or graduate standing.

**CHEM 5061 (3) Advanced Inorganic Chemistry 2**

Lectures in physical inorganic chemistry with an emphasis on topics for understanding modern solar energy conversion to electricity and fuels. Includes a description of bonding and properties of coordination compounds in terms of the ligand field and molecular orbital theories. The primary research literature will be used to motivate exploration of relevant themes including spectroscopy, electron transfer, energy transfer, bioenergetic conversion, and small-molecule activation.

**Requisites:** Requires prerequisite course of CHEM 4011 (minimum grade C-) or graduate standing.

**CHEM 5121 (3) Practical Laboratory Skills for Analytical Chemistry**

Practical laboratory skills for research in experimental analytical and atmospheric chemistry (and related fields such as physical chemistry). Short lectures followed by hands-on laboratory practice and discussion. Topics covered include gases and flows; electricity and signals; key environmental measurements; data acquisition and other advanced topics.

**Requisites:** Restricted to graduate students only.

**Grading Basis:** Letter Grade

**CHEM 5131 (3) Computer Programming and Data Analysis for Chemists**

Provides an introduction to computer programming and data analysis skills that are a fundamental part of graduate research. The programming section of the course introduces the coding skills necessary for simulating, analyzing and visualizing data using IGOR Pro and for acquiring data and analyzing data using LabVIEW. Basic concepts in statistics and error analysis are also covered.

**Requisites:** Restricted to graduate students only.

**Recommended:** Prerequisites CHEM 4511 or CHEM 4171.

**Grading Basis:** Letter Grade

**CHEM 5141 (3) Environmental Water and Soil Chemistry**

Application of basic chemical principles to understanding the processes that determine the chemical composition of oceans, lakes, rivers, soils and sediments. Topics include air-water exchange; acid-base, redox, coordination, precipitation and dissolution, ion exchange and sorption reactions; nutrient chemistry; and the use of simple equilibrium and kinetic models for describing the chemistry of inorganic and organic species in air-water-soil systems.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 4141

**Requisites:** Restricted to graduate students only.

**CHEM 5151 (3) Atmospheric Chemistry**

Lect. Basic kinetics and photochemistry of atmospheric species. Stratospheric chemistry with emphasis on processes controlling ozone abundance. Tropospheric chemistry focusing on photochemical smog, acid deposition, oxidative capacity of the atmosphere and global climate change.

**Equivalent - Duplicate Degree Credit Not Granted:** ATOC 5151

**Requisites:** Restricted to graduate students only.

**Recommended:** Prerequisite one semester of college-level chemistry.

**CHEM 5152 (3) Advanced Atmospheric Chemistry**

Follows Graduate Atmospheric Chemistry (CHEM 5151) and explores advanced topics in atmospheric chemistry, such as secondary aerosol formation, oxidant formation, the chemistry of global climate change and/or design of advanced laboratory experiments.

**Equivalent - Duplicate Degree Credit Not Granted:** ATOC 5152

**Recommended:** Prerequisite CHEM 5151 or ATOC 5151.

**CHEM 5161 (3) Analytical Atmospheric Spectroscopy**

Optical spectrochemical analysis, atmospheric transmittance, including atomic and molecular spectroscopy, line-by-line spectral databases such as HITRAN, absorption, emission, fluorescence, scattering processes of gases, surface enhancements, aerosols, optical spectroscopic instrument components, and techniques, and their applications to atmospheric, and environmental problems. Department enforced prereq., undergraduate physical chemistry or instructor consent.

**Requisites:** Restricted to graduate students only.

**CHEM 5171 (3) Electroanalytical Chemistry**

Lect. Establishes a background for understanding electrochemical systems through a review of the relevant thermodynamic, kinetic and electronic principles. Compares classical and modern electrochemical methods of analysis. Several special topics are discussed in depth. Department enforced prerequisite: undergraduate physical chemistry or instructor consent.

**Requisites:** Restricted to graduate students only.

**CHEM 5181 (3) Mass Spectrometry, Chromatography, and Computer Programming**

Covers mass spectrometry, including instrumentation, ionization techniques, and interpretation of spectra. Analytical separation methods such as gas and liquid chromatography, ion mobility, and capillary electrophoresis. Introduction to atmospheric chemistry applications. Computer programming (Igor and LabVIEW) and simulation of instrumentation and processes. Department prerequisite: basic computer programming (or willingness to work hard on it), and undergraduate physics, statistics, and physical chemistry.

**Requisites:** Restricted to graduate students only.

**CHEM 5251 (3) Materials Chemistry and Properties**

Lect. Understanding of materials from chemistry perspective including metals, oxides, semiconductors and polymers. Basic description of chemical preparation of materials. Overview of fundamental properties of materials including structural, chemical, mechanical, thermal, electrical, and optical properties. Description of behavior of materials and various applications in modern technology. Discussion of materials characterization methods.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 4251

**Requisites:** Requires prerequisite course of CHEM 4431 or CHEM 4531 (all minimum grade C-) or graduate standing.

**CHEM 5261 (3) Organic Materials: Structures and Functions**

Overview of the preparation and functioning mechanism of novel organic materials that have recently been developed, including conductive polymers, 2-D macrocyclic structures, 3-D molecular cages, molecular machines/muscles/switches, fullerene derivatives and carbon nanotube composites. Emphasizes the use of organic and physical chemistry as tools to develop novel materials and probe their structure-property relationship.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 4261

**Requisites:** Requires prerequisite course of CHEM 4431 or CHEM 4531 (all minimum grade C-) or graduate standing.

**CHEM 5271 (3) Chemistry of Solar Energy**

Chemical principles of conversion of solar energy into electricity and fuels in molecular and semiconductor-based systems. Overview of solid-state electronic structure of materials and interfaces, light-matter interactions, principles of harvesting photoexcited currents and useful chemical species. Description of processes utilized in established and emerging solar energy technologies.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 4271

**Requisites:** Requires prerequisite course of CHEM 4431 or CHEM 4531 (all minimum grade C-) or graduate standing.

**CHEM 5281 (3) Semiconductor Processing and Device Fabrication**

Understanding of semiconductor processing and device fabrication from chemistry perspective. Overview of processing steps used to fabricate inorganic semiconductor devices including deposition, patterning and etching techniques. Description of process integration during device fabrication. Discussion of key issues facing advanced semiconductor fabrication.

**Requisites:** Restricted to graduate students only.

**Grading Basis:** Letter Grade

**CHEM 5311 (3) Advanced Synthetic Organic Chemistry**

Lect. Surveys synthetic transformations emphasizing important functional group transformations and carbon-carbon, bond-forming reactions. Required of all organic chemistry graduate students. Department enforced prerequisite: one year of organic chemistry or graduate standing.

**CHEM 5321 (3) Advanced Physical Organic Chemistry**

Lect. Modern concepts of physical organic chemistry and their use in interpreting data in terms of mechanisms of organic reactions and reactivities of organic compounds. Required of all organic chemistry graduate students. Department enforced prerequisites: one year of organic chemistry and one year of physical chemistry or graduate standing.

**CHEM 5331 (3) Advanced Spectroscopic Techniques in Organic Chemistry**

Lect. Advanced spectroscopic techniques for structure and determination in organic chemistry. Emphasizes proton and carbon-13 NMR spectroscopy. Department enforced prerequisites: one year of organic chemistry and one year of physical chemistry or graduate standing.

**CHEM 5501 (3) Advanced Topics in Physical Chemistry**

Covers various topics in physical chemistry focusing on their mathematical and physical background. Topics include the application of classical mechanics and electrodynamics in chemistry, the classical mechanics background for the description of atoms and molecules, the use of vector spaces in wave mechanics and quantum mechanics and the classical description of spectroscopy in terms of interaction of light and matter. Department enforced prerequisites: undergraduate physical chemistry, graduate standing or instructor consent.

**Requisites:** Restricted to graduate students only.

**CHEM 5531 (3) Statistical Mechanics**

Lect. Fundamental concepts of quantum and classical statistical mechanics. Applications to properties of gases, liquids, solids, spin and polymer systems. Reaction, fluctuation, nucleation and relaxation phenomena. Department enforced prerequisite: undergraduate physical chemistry.

**Requisites:** Restricted to graduate students only.

**CHEM 5541 (3) Chemical Dynamics**

Lect. Discussion of mechanism and rate of chemical reactions from a fundamental point of view. Discusses nature of collision and develops concepts of cross section and rate constant. Theories of elementary bimolecular and decay processes are critically examined. Department enforced prerequisite: undergraduate physical chemistry.

**Requisites:** Restricted to graduate students only.

**CHEM 5555 (4) Theoretical and Computational Chemistry**

Explores computational methods to understand chemical systems. Topics include: atomic and molecular electronic structure calculations, Monte Carlo and molecular dynamics simulations and thermodynamic calculations.

**Equivalent - Duplicate Degree Credit Not Granted:** CHEM 4555

**Requisites:** Restricted to graduate students only.

**Grading Basis:** Letter Grade

**CHEM 5571 (3) Surface Science**

Lect. Principles of surface science with emphasis on fundamental surface phenomena, surface techniques and surface chemistry. Basic description of surfaces, adsorbate-surface interactions, surface kinetics and methods of surface analysis. Surface science of heterogeneous catalysis, semiconductor processing, and environmental interfaces. Department enforced prerequisites: undergraduate physical chemistry and graduate standing or instructor consent.

**Requisites:** Restricted to graduate students only.

**CHEM 5581 (3) Introductory Quantum Chemistry**

Lect. Basic principles and techniques of quantum mechanics with applications to questions of chemical interest. Quantum dynamics of atoms, molecules and spin; electronic structure of atoms and molecules. Department enforced prerequisite: two semesters of physical chemistry and graduate standing or instructor consent.

**Requisites:** Restricted to graduate students only.

**CHEM 5591 (3) Advanced Molecular Spectroscopy**

Lect. Rotational, vibrational and electronic spectra of molecules, and their interpretation in terms of the quantum theory of molecular structure.

Department enforced prerequisites: two semesters of physical chemistry and graduate standing or instructor consent.

**Requisites:** Restricted to graduate students only.

**CHEM 6001 (1) Seminar: Inorganic Chemistry**

Student, faculty, and guest presentations and discussions of current research in inorganic chemistry and related topics (transition element and main group element compound properties, inorganic compound in biological, industrial, and materials applications). Required of all inorganic chemistry graduate students. Credit deferred until presentation of satisfactory seminar.

**Repeatable:** Repeatable for up to 3.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 6021 (1-3) Special Topics in Inorganic Chemistry**

Lect. Subjects of current interest in inorganic chemistry. Primarily used for graduate-level presentations of special topics by visiting and resident faculty. Variable class schedule.

**Repeatable:** Repeatable for up to 7.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 6031 (3) Special Topics in Nanoscience**

Introduces the synthesis, physical properties, and applications of nanometer-scale materials and devices. Includes synthesis of metal and semiconductor nanoparticles and nanowires, optical and electronic properties of nanoscale systems, and applications in biotechnology and energy.

**Requisites:** Requires prerequisite course of CHEM 4431 or CHEM 4511 (all minimum grade B-) or graduate standing.

**CHEM 6101 (1) Seminar: Analytical Chemistry**

Student, faculty, and guest presentations and discussions of current research in analytical chemistry. Required of all analytical chemistry graduate students. Credit deferred until presentation of satisfactory seminar.

**Repeatable:** Repeatable for up to 3.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 6111 (1-3) Special Topics in Analytical Chemistry**

Lect. Subjects of current interest in analytical chemistry. Used for graduate-level presentations of special topics by visiting and resident faculty. Variable class schedule.

**Repeatable:** Repeatable for up to 7.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 6301 (1-3) Seminar in Organic Chemistry**

Discussions principally concerned with recent literature in organic chemistry. Required of all organic chemistry graduate students.

**Repeatable:** Repeatable for up to 3.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 6311 (1-3) Special Topics in Synthetic Organic Chemistry**

Lect. Selected topics in synthetic organic chemistry, encompassing both methods and/or total synthesis of complex molecules.

**Requisites:** Requires prerequisite course of CHEM 5311 (minimum grade B-). Restricted to graduate students only.

**CHEM 6321 (1-3) Special Topics in Physical Organic Chemistry**

Lect. Selected topics in physical organic chemistry, which may include photochemistry, carbene chemistry, free radical chemistry, molecular orbital methods, organic materials, or gas phase ion chemistry.

**Requisites:** Requires prerequisite course of CHEM 5321 (minimum grade B-). Restricted to graduate students only.

**CHEM 6401 (1-3) Seminar: Physical Chemistry**

Student, faculty, and guest presentations of current research in physical chemistry. Discussion of research topics related to the subject of weekly physical chemistry/chemical physics seminar and appropriate journal articles.

**Repeatable:** Repeatable for up to 3.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 6411 (1-3) Advanced Topics in Physical Chemistry**

Lect.

**Requisites:** Restricted to graduate students only.

**CHEM 6801 (0) Departmental Research Seminar**

Lectures by visiting scientists and occasionally by staff members and graduate students on topics of current research. Meets once a week. Required for all graduate students in chemistry.

**Repeatable:** Repeatable for up to 3.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 6901 (1-6) Research in Chemistry**

**Repeatable:** Repeatable for up to 15.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 6941 (1) Master's Candidate for Degree**

Registration intended for students preparing for a thesis defense, final examination, culminating activity, or completion of degree.

**Requisites:** Restricted to graduate students only.

**CHEM 6951 (1-6) Master's Thesis**

**Requisites:** Restricted to graduate students only.

**CHEM 7021 (2) Seminar: Structural Inorganic Chemistry**

Current research in the area of structural inorganic chemistry. Concerns topics related to electronic and molecular structure of transition metal complexes. Department consent required.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 7101 (2) Seminar: Chromatography and Trace Analysis**

Student and faculty discussions and reports on research advances in chromatography, trace analysis and environmental chemistry. Department consent required.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 7111 (2) Seminar: Electrochemistry**

Student and faculty discussions and reports on research advances in electrochemistry. Department consent required.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 7131 (1) Seminar in Atmospheric Aerosol Chemistry**

Discusses advances in atmospheric aerosol chemistry, with emphasis on new methods for analysis and their application to laboratory and field studies.

**Repeatable:** Repeatable for up to 2.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**Recommended:** Prerequisites CHEM 5151 and CHEM 5181.

**CHEM 7161 (1) Seminar: Heterogeneous Atmospheric Chemistry**

Topics in atmospheric chemistry emphasizing the structure and reactivity of atmospheric particulates. Presentations on current research and critical evaluations of recent literature. Department consent required.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 7201 (1) Seminar: Synthetic and Bioorganic Chemistry**

Seminar in organic and bioorganic chemistry, particularly the synthesis of complex organic molecules and their interactions with biopolymers. Included is the study of the synthesis and biological functions of carbohydrates, peptides, proteins and related molecules. Prereq., instructor consent.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**CHEM 7211 (1) Seminar: Topics in Synthetic Methodology and Natural Product Synthesis**

Discussion of contemporary synthetic organic chemistry with a focus on new methodology and total synthesis of natural products.

**Requisites:** Restricted to graduate students only.

**CHEM 7221 (1) Seminar: Photochemistry and Free Radical Chemistry**

Current research in areas of organic free radical chemistry, photochemistry, and related topics are presented and discussed. Department consent required.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 7231 (1) Seminar: Reactive Intermediates**

Application of contemporary ideas of chemical physics to organic molecules. Special attention to structures and bonding in organic ions and radicals. Department consent required.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 7241 (1) Seminar: Synthetic Organic Chemistry**

Series of seminars on directed total synthesis. Emphasizes modern synthetic methodology and applications to total synthesis of natural products. Department consent required.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 7251 (1) Seminar: Selected Topics in Chemical Genetics**

Discusses the brief history of the emerging field of chemical genetics, and focuses on the recent development of concepts, techniques, applications, and its impact on both science and human health.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 7271 (1) Seminar: Picosecond Dynamics of Reactions**

Includes development and application of picosecond laser spectroscopy to organic and organometallic reactions. Emphasizes relationship between current theoretical developments and experiments. Department consent required.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 7281 (1) Seminar: Molecular Self-Assembly**

Discusses current topics and recent advances in molecular self-assembly, with emphasis on new liquid crystal designs and applications.

**Repeatable:** Repeatable for up to 2.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 7291 (1) Seminar: Physical Organic Chemistry**

Modern experimental techniques and theoretical models in physical organic chemistry are discussed in relation to the development of new materials, such as molecular size tinkertoys to the development of novel photochemical systems and their spectroscopies. Department consent required.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 7301 (1) Seminar: Synthetic and Mechanistic Chemistry**

Discusses particularly the synthesis of complex organic molecules and the mechanism of reagents used in organic synthesis. Includes a study of transition metal mediated organic reactions. Department consent required.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 7311 (1) Seminar: Selected Topics in Organic Materials**

Current research in the area of organic/materials chemistry. Concerns topics related to organic materials synthesis, carbon nanotube functionalization, artificial photosynthesis, gas storage and catalysis.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 7401 (1) Seminar in Photochemical Reaction Control**

Discusses progress towards control of molecular reactivity using light, including synthetic methods for creating control subjects. Emphasizes new methods to achieve coherent control.

**Repeatable:** Repeatable for up to 2.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 7421 (2) Seminar: Negative Ion Chemistry**

Chemistry of negative ions; experimental methods and designs; laser spectroscopy of ions; theoretical methods; reactive dynamics of ions in the gas phase. Department consent required.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 7431 (1) Seminar: Topics in Theoretical Chemical Physics**

Seminars presented on a variety of topics in theoretical chemical physics. Molecular collisions and unimolecular dynamics predominantly featured. Department consent required.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 7441 (2) Research Seminar: Theoretical Chemistry**

Studies theoretical description of molecular dynamics as related to rate processes. Focuses on chemical reactions in liquids, absorption-desorption on surfaces, nucleation reactions, and energy flow in molecules. Department consent required.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 7461 (1) Seminar: Gas Phase Ion Chemistry**

Studies gas phase ion chemistry relevant to thermochemical measurements and atmospheric, interstellar, and biomedical applications.

**Requisites:** Restricted to graduate students only.

**CHEM 7471 (1) Seminar in Ultrafast Spectroscopy of Proteins**

Discusses advances and developments in biomolecular dynamics, and considers the connection of protein dynamics with function. Emphasizes experimental studies via ultrafast laser spectroscopy.

**Repeatable:** Repeatable for up to 2.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 7481 (2) Seminar: Molecular Spectroscopy and Photochemistry**

Discussion and presentation of current research in spectroscopy and photochemistry of organic as well as organometallic systems. Reviews state of the art techniques available for the theoretical and experimental characterization of excited states. Department consent required.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to graduate students only.



**CHEM 7491 (1) Seminar: Molecular Vibrational Dynamics**

Topics pertaining to vibrational dynamics of small molecules are discussed, with particular emphasis upon IR laser spectroscopy, van der Waals' clusters, vibrationally induced dipole moments, and predissociation. Discussion of current research and recently published literature. Department consent required.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 7501 (1) Seminar: Theoretical Molecular Dynamics**

Variety of topics in theoretical chemical physics, emphasizing dynamics of molecules in dissipative environments or in radiation fields. Department consent required.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 7511 (1) Seminar: Reaction Dynamics in Condensed Phases**

Studies elementary steps in chemical reactions and their observation by ultrafast spectroscopy. Department consent required.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 7521 (1) Seminar: Atmospheric Kinetics and Photochemistry**

Discusses laboratory studies of degradation mechanisms. Applies these studies to atmospheric phenomena such as global warming and stratospheric ozone loss. Department consent required.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 7531 (1) Seminar: Surface Chemistry and Thin Film Growth**

Topics in surface chemistry and thin film growth with focus on atomic layer deposition (ALD) and molecular layer deposition (MLD). Properties of thin films grown using ALD and MLD. Applications of thin films in areas including flexible displays, energy storage and catalysis. Department consent required.

**Repeatable:** Repeatable for up to 6.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 7551 (1) Selected Topics in Ion Spectroscopy**

Treats current topics in the spectroscopy of ions. Seminar lectures are given by graduate students on their research and on literature topics, and the results of both in-house and external research groups are studied. Additionally, ideas for interesting directions of research and new experiments are proposed and discussed.

**Repeatable:** Repeatable for up to 2.00 total credit hours.

**Requisites:** Restricted to graduate students only.

**CHEM 8991 (1-10) Doctoral Dissertation**

All doctoral students must register for 30 hours of dissertation credit as part of the requirements for the degree. For a detailed discussion of doctoral dissertation credit, refer to the Graduate School section.

**Repeatable:** Repeatable for up to 30.00 total credit hours.

**Requisites:** Restricted to graduate students only.