

# Chemistry (CHEM)

Courses primarily for undergraduates:

## CHEM 050. Preparation for College Chemistry.

(3-0) Cr. arr. F.S.SS. *Prereq:* 1 year high school algebra

An in-depth active learning experience designed to impart the fundamental concepts and principles of chemistry, with an emphasis on mathematics skills and logical thinking. For students intending to enroll in general chemistry and who have not taken high school chemistry or who have not had a high school college preparatory chemistry course who need a review of chemical problem solving and chemical concepts. Credit for Chem 50 does not count toward graduation.

## CHEM 101. Chemistry Learning Community Orientation.

(1-0) Cr. 1. F.S. *Prereq:* Member of the Chemistry Learning Community.

Integration of first year and transfer students into the chemistry program. Introduction and overview of degree requirements and support services on campus, assistance with transition to college and community life, and team-building and leadership activities. Offered on a satisfactory-fail basis only.

## CHEM 102L. Physical Sciences for Elementary Education.

(Cross-listed with PHYS). (1-5) Cr. 3. S. *Prereq:* MATH 195 or MATH 140

Introduction to physics and chemistry via weekly, guided-inquiry laboratories. Topics to include states of matter and changes in states of matter, sound, light, electricity, magnetism, heat, forces and how they are related to an object's motion.

## CHEM 110. Cutting-Edge Chemistry: Research and Career Opportunities.

(1-0) Cr. 1. F.

Overview of careers in chemistry: industrial, governmental, and academic careers; literature and compound search instruction; professional ethics; and an introduction to joining a research lab. For students majoring or minoring in chemistry or chemistry-related fields. Offered on a satisfactory-fail basis only.

## CHEM 160. Chemistry in Modern Society.

(3-0) Cr. 3. F.S.

Aspects of chemistry visible to a non-scientist in our society. A survey of selected areas of chemistry with emphasis on the interface between chemistry and other fields of human activity.

## CHEM 163. College Chemistry.

(4-0) Cr. 4. F.S. *Prereq:* 1 year of high school algebra and geometry and Chem 50, or 1 year of high school chemistry; and credit or enrollment in CHEM 163L

A general survey of chemistry with an emphasis on conceptual problems for those who are not physical and biological science or engineering majors. Nomenclature, chemical reactions, stoichiometry, atomic structure, periodic properties, chemical bonding, states of matter, solutions, thermochemistry, acid-base theory, oxidation-reduction reactions, basic chemical kinetics, and chemical equilibrium. Only one of Chem 163, 167, 177, or 201 may count toward graduation.

## CHEM 163L. Laboratory in College Chemistry.

(0-3) Cr. 1. F.S. *Prereq:* Credit or enrollment for credit in CHEM 163

Laboratory to accompany CHEM 163. Must be taken with CHEM 163. Only one of Chem 163L, CHEM 167L, and CHEM 177L may count toward graduation.

## CHEM 167. General Chemistry for Engineering Students.

(4-0) Cr. 4. F.S. *Prereq:* MATH 140 or high school equivalent and 1 year of high school chemistry or CHEM 50

Principles of chemistry and properties of matter explained in terms of modern chemical theory with emphasis on topics of general interest to the engineer. Only one of Chem 163, 167, 177, or 201 may count toward graduation.

## CHEM 167L. Laboratory in General Chemistry for Engineering.

(0-3) Cr. 1. F.S. *Prereq:* Credit or enrollment for credit in CHEM 167

Laboratory to accompany 167. Only one of Chem 163L, 167L, and 177L may count toward graduation.

## CHEM 177. General Chemistry I.

(4-0) Cr. 4. F.S.SS. *Prereq:* MATH 140 or high school equivalent, and CHEM 50 or 1 year high school chemistry, and credit or enrollment in CHEM 177L. Chemistry and biochemistry majors may consider taking CHEM 201

The first semester of a two semester sequence which explores chemistry at a greater depth and with more emphasis on concepts, problems, and calculations than 163. Recommended for physical and biological science majors, chemical engineering majors, and all others intending to take 300-level chemistry courses. Principles and quantitative relationships, stoichiometry, chemical equilibrium, acid-base chemistry, thermochemistry, rates and mechanism of reactions, changes of state, solution behavior, atomic structure, periodic relationships, chemical bonding. Only one of Chem 163, 167, 177, or 201 may count toward graduation.

## CHEM 177L. Laboratory in General Chemistry I.

(0-3) Cr. 1. F.S.SS. *Prereq:* Credit or enrollment for credit in CHEM 177

Laboratory to accompany 177. 177L must be taken with 177. Only one of Chem 163L, 167L, and 177L may count toward graduation.

## CHEM 177N. Laboratory in General Chemistry I.

(0-3) Cr. 1. F.S. *Prereq:* Credit or enrollment for credit in CHEM 177. For chemistry and biochemistry majors

Laboratory to accompany CHEM 177. CHEM 177N must be taken with CHEM 177. Only one of Chem 163L, CHEM 167L, and CHEM 177N may count toward graduation.

## CHEM 178. General Chemistry II.

(3-0) Cr. 3. F.S.SS. *Prereq:* CHEM 177, CHEM 177L

Continuation of 177. Recommended for physical or biological science majors, chemical engineering majors, and all others intending to take 300-level chemistry courses. Credit by examination (test-out exams) for 178 is available only to students who are not currently enrolled in the course.

## CHEM 178L. Laboratory in College Chemistry II.

(0-3) Cr. 1. F.S.SS. *Prereq:* CHEM 177L and credit or enrollment for credit in CHEM 178

Laboratory to accompany 178. 178L is not a necessary co-requisite with 178.

## CHEM 201. Advanced General Chemistry.

(5-0) Cr. 5. F. *Prereq:* MATH 140 or high school equivalent, one year of high school chemistry, and one year high school physics or advanced chemistry. Co-enrollment in CHEM 201L.

A one-semester course in general chemistry designed to give students an in-depth, broad-based view of modern chemistry, and, in part, to facilitate participation in independent undergraduate research. Topics include stoichiometry, atomic and molecular structure, chemical bonding, kinetics, chemical equilibria, and thermodynamics. Discussion of current trends in various chemical disciplines, which may be given by guest experts in chemistry, biochemistry, and chemical engineering, will help the student appreciate the scope of the chemical sciences and how research is carried out. Only one of Chem 163, 167, 177, or 201 may count toward graduation.

## CHEM 201L. Laboratory in Advanced General Chemistry.

(0-3) Cr. 1. *Prereq:* Credit or enrollment for credit in CHEM 201

Laboratory to accompany 201. Introductory lab experience in synthesis and analysis to prepare students for research activities. 201L must be taken with 201. Only one of 163L, 167L, 177L, 177N or 201L may count toward graduation.

## CHEM 211. Quantitative and Environmental Analysis.

(2-0) Cr. 2. F.S. *Prereq:* CHEM 163 and CHEM 163L, credit or enrollment in CHEM 178, or CHEM 201 and CHEM 201L; and concurrent enrollment in CHEM 211L

Theory and practice of elementary volumetric, chromatographic, electrochemical and spectrometric methods of analysis. Chemical equilibrium, sampling, and data evaluation. Emphasis on environmental analytical chemistry; the same methods are widely used in biological and materials sciences as well.

## CHEM 211L. Quantitative and Environmental Analysis Laboratory.

(0-6) Cr. 2. F.S. *Prereq:* Credit or enrollment in CHEM 163 and CHEM 163L, or CHEM 178; and concurrent enrollment in CHEM 211

Introductory laboratory experience in volumetric, spectrometric, electrochemical and chromatographic methods of chemical analysis.

## CHEM 231. Elementary Organic Chemistry.

(3-0) Cr. 3. F.S.SS. *Prereq:* CHEM 163, CHEM 163L, or CHEM 177, CHEM 177L; credit or enrollment in CHEM 231L

A survey of modern organic chemistry including nomenclature, structure and bonding, and reactions of hydrocarbons and important classes of natural and synthetic organic compounds. For students desiring only an elementary course in organic chemistry. Students in physical or biological sciences and premedical or preveterinary curricula should take the full year sequence 331 and 332 (with the accompanying laboratories 331L and 332L). Only one of Chem 231 and 331 or BBMB 221 may count toward graduation.

## CHEM 231L. Laboratory in Elementary Organic Chemistry.

(0-3) Cr. 1. F.S.SS. *Prereq:* Credit or enrollment for credit in CHEM 231; CHEM 163L or CHEM 177L

Laboratory to accompany 231. 231L must be taken with 231. Only one of Chem 231L and 331L may count toward graduation.

## CHEM 298. Cooperative Education.

Cr. R. F.S.SS. *Prereq:* Permission of the Department cooperative education coordinator; sophomore classification

Required of all cooperative education students. Students must register for this course prior to commencing each work period.

**CHEM 299. Undergraduate Research (for Freshmen and Sophomores).**  
Cr. arr. Repeatable, maximum of 6 credits. *Prereq: Permission of staff member with whom student proposes to work*

**CHEM 301. Inorganic Chemistry.**  
(2-0) Cr. 2. S. *Prereq: CHEM 324*

Atomic and molecular structure and bonding principles; molecular shapes and symmetry; acids and bases; solid-state structures and properties; inorganic chemistry of H, B, C. Nonmajor graduate credit.

**CHEM 316. Instrumental Methods of Chemical Analysis.**  
(2-0) Cr. 2. F. *Prereq: CHEM 211, CHEM 211L, Math 166, and concurrent enrollment in CHEM 316L; PHYS 222 recommended*

Quantitative and qualitative instrumental analysis. Operational theory of instruments, atomic and molecular absorption and emission spectroscopy, electroanalysis, mass spectrometry, liquid and gas chromatography, electrophoresis, literature of chemical analysis. Nonmajor graduate credit.

**CHEM 316L. Instrumental Analysis Laboratory.**  
(0-6) Cr. 2. F. *Prereq: Credit or enrollment in CHEM 316*

Advanced laboratory experience in UV-visible spectrophotometry, atomic absorption and emission spectrometry, electrochemistry, gas and liquid chromatography, electrophoresis, mass spectrometry, and other instrumental methods. Nonmajor graduate credit.

**CHEM 321L. Laboratory in Physical Chemistry.**  
(1-3) Cr. 2. S. *Prereq: Credit or enrollment in CHEM 324 or CHEM 325.*  
Error analysis; use of computers for interfacing to experiments and for data analysis; thermodynamics, infrared and optical spectroscopy, lasers. Not applicable towards the B.S. degree in Chemistry. Nonmajor graduate credit. Only one of Chem 321L and 322L may count toward graduation.

**CHEM 322L. Laboratory in Physical Chemistry.**  
(1-6) Cr. 3. S. *Prereq: CHEM 324 or CHEM 325.*  
Error analysis; use of computers for interfacing to experiments and for data analysis; thermodynamics, surface science, infrared and optical spectroscopy, lasers. Nonmajor graduate credit. Only one of Chem 321L and 322L may count toward graduation.

**CHEM 324. Introductory Quantum Mechanics.**  
(3-0) Cr. 3. F.S. *Prereq: CHEM 178, MATH 166, PHYS 222 recommended.*  
Quantum mechanics, atomic and molecular structure, spectroscopy, kinetic theory of gases, chemical kinetics. Nonmajor graduate credit.

**CHEM 325. Chemical Thermodynamics.**  
(3-0) Cr. 3. F.S. *Prereq: CHEM 178, MATH 166, PHYS 222 recommended*  
Classical thermodynamics 1st, 2nd, and 3rd laws with applications to gases and interfacial systems, multicomponent, multiphase equilibrium of reacting systems, surface chemistry, and electrochemical cells. Students taking a two-semester physical chemistry sequence are advised to take 324 first; in the spring semester, a molecular-based section of this course, stressing statistical thermodynamics, is offered for which knowledge of 324 is useful. Nonmajor graduate credit.

**CHEM 331. Organic Chemistry I.**  
(3-0) Cr. 3. F.S.SS. *Prereq: CHEM 178 or CHEM 201, enrollment in CHEM 331L highly recommended*

The first half of a two semester sequence. Modern organic chemistry including nomenclature, synthesis, structure and bonding, reaction mechanisms. For students majoring in physical and biological sciences, premedical and pre-veterinary curricula, chemistry and biochemistry. Students desiring only one semester of organic chemistry should take 231 and 231L, not 331. Nonmajor graduate credit. Only one of Chem 231 and 331 may count toward graduation.

**CHEM 331L. Laboratory in Organic Chemistry I.**  
(0-3) Cr. 1. F.S.SS. *Prereq: Credit or enrollment for credit in CHEM 331, CHEM 177L*

Laboratory to accompany 331. Chemistry and biochemistry majors are encouraged to take 333L. Only one of Chem 231L and 331L may count toward graduation.

**CHEM 332. Organic Chemistry II.**  
(3-0) Cr. 3. F.S.SS. *Prereq: CHEM 331, enrollment in CHEM 332L highly recommended*  
Continuation of 331. Modern organic chemistry including nomenclature, synthesis, structure and bonding, reaction mechanisms, natural products, carbohydrates and proteins. For students majoring in physical and biological sciences, premedical and pre-veterinary curricula, chemistry and biochemistry. Nonmajor graduate credit.

**CHEM 332L. Laboratory in Organic Chemistry II.**  
(0-3) Cr. 1. F.S.SS. *Prereq: CHEM 331L, credit or enrollment for credit in CHEM 332*

Laboratory to accompany 332. Chemistry and biochemistry majors are encouraged to take 334L.

**CHEM 333L. Laboratory in Organic Chemistry I (for Chemistry and Biochemistry Majors).**  
(0-6) Cr. 2. F. *Prereq: Credit or enrollment for credit in CHEM 331*  
Laboratory to accompany 331 for chemistry and biochemistry majors.

**CHEM 334L. Laboratory in Organic Chemistry II (for Chemistry and Biochemistry Majors).**  
(0-6) Cr. 2. S. *Prereq: CHEM 333L, credit or enrollment for credit in CHEM 332*  
Laboratory to accompany 332 for chemistry and biochemistry majors.

**CHEM 398. Cooperative Education.**  
Cr. R. F.S.SS. *Prereq: Permission of the Department cooperative education coordinator; junior classification*  
Required of all cooperative education students. Students must register for this course prior to commencing each work period.

**CHEM 399. Undergraduate Research.**  
Cr. arr. *Prereq: Permission of instructor with whom student proposes to work and junior or senior classification*  
No more than six total credits of Chem 399 and Chem 499 may count toward graduation.

**CHEM 401L. Inorganic Chemistry Laboratory.**  
(0-3) Cr. 1. F. *Prereq: CHEM 301*  
Preparation and characterization of inorganic and organometallic compounds by modern techniques. For students majoring in chemistry or biochemistry. Nonmajor graduate credit.

**CHEM 402. Advanced Inorganic Chemistry.**  
(3-0) Cr. 3. F. *Prereq: CHEM 301; CHEM 331 recommended*  
Chemistry of the d and f metals. Structure, bonding, electronic spectra, and reaction mechanisms. Aspects of organometallic solid state and bioinorganic chemistry. Nonmajor graduate credit.

**CHEM 490. Independent Study.**  
Cr. arr. *Prereq: Completion of 6 credits in chemistry at the 300 level or higher and permission of instructor*  
No more than 9 credits of Chem 490 may count toward graduation.

**CHEM 498. Cooperative Education.**  
Cr. R. F.S.SS. *Prereq: Permission of the Department cooperative education coordinator; senior classification*  
Required of all cooperative education students. Students must register for this course prior to commencing each work period.

**CHEM 499. Senior Research.**  
Cr. 2-3. Repeatable, maximum of 6 credits. *Prereq: Permission of instructor with whom student proposes to work; B average in all chemistry, physics, and mathematics courses*  
Research in chosen area of chemistry, with final written report as senior thesis. This course should be elected for two consecutive semesters. For students majoring in chemistry. No more than six total credits for Chem 399 and 499 may count toward graduation.

**Courses primarily for graduate students, open to qualified undergraduates:**

**CHEM 501L. Inorganic Preparations.**  
(0-3) Cr. 1. F. *Prereq: CHEM 402*  
Preparation and characterization of inorganic and organometallic compounds by modern research techniques.

**CHEM 502. Advanced Inorganic Chemistry.**  
(3-0) Cr. 3. F. *Prereq: CHEM 301; CHEM 331 recommended*  
Chemistry of the main group (s, p) and transition (d, f) metals. Structure, bonding, electronic spectra, and reaction mechanisms. Aspects of organometallic, solid state, bioinorganic, and nano chemistry.

**CHEM 503. Bioinorganic Chemistry.**  
(Cross-listed with BBMB). (2-0) Cr. 2. Alt. S., offered 2012. *Prereq: CHEM 402 or BBMB 405*  
Essential elements: transport and storage of ions and of oxygen; metalloenzymes and metallocoenzymes; electron-transfer processes in respiration and photosynthesis; metabolism of nonmetals and redox processes involved in it; medicinal aspects of inorganic chemistry.

**CHEM 505. Physical Inorganic Chemistry.**

(3-0) Cr. 3. S. *Prereq: CHEM 402 or CHEM 502 and CHEM 324*  
Elementary group theory and molecular orbital theory applied to inorganic chemistry. Spectroscopic methods of characterization of inorganic compounds and organometallic compounds.

**CHEM 511. Advanced Analytical Chemistry.**

(3-0) Cr. 3. F. *Prereq: CHEM 316 and CHEM 316L*  
General methods of quantitative inorganic and organic analysis. Aqueous and nonaqueous titrimetry; selective reagents; sampling and sample dissolution; modern instrumentation; sensors; atomic and molecular microscopy; bioanalytical methods; data evaluation; chemometrics; and analytical literature.

**CHEM 512. Electrochemical Methods of Analysis.**

(3-0) Cr. 3. F. *Prereq: CHEM 316 and CHEM 316L, CHEM 324, and CHEM 322L*  
Principles of convective-diffusional mass transport in electroanalysis. Applications of potentiometry, voltammetry, and coulometry. Introduction to heterogeneous and homogeneous kinetics in electroanalysis. Analog and digital circuitry. Interfacing.

**CHEM 513. Analytical Molecular and Atomic Spectroscopy.**

(3-0) Cr. 3. S. *Prereq: CHEM 316 and CHEM 316L, CHEM 324, CHEM 322L*  
Introduction to physical optics and design of photometric instruments. Principles of absorption, emission, fluorescence, and Raman spectroscopy. Error and precision of optical methods. Ultraviolet, visible, and infrared methods of qualitative and quantitative organic and inorganic analysis.

**CHEM 516. Analytical Separations.**

(3-0) Cr. 3. F. *Prereq: CHEM 316 and CHEM 316L, CHEM 324, CHEM 322L*  
Principles and examples of inorganic and organic separation methods applied to analytical chemistry. Solvent extraction, volatilization, ion exchange, liquid and gas chromatography, and electrophoresis.

**CHEM 531. Organic Synthesis I.**

(2-0) Cr. 2. S. *Prereq: CHEM 332*  
Survey of organic functional group transformations.

**CHEM 532. Organic Synthesis II.**

(2-0) Cr. 2. F. *Prereq: CHEM 531*  
Synthesis of complex organic compounds including natural products.

**CHEM 537. Physical Organic Chemistry I.**

(3-0) Cr. 3. F. *Prereq: CHEM 332*  
Molecular structure, stereochemistry, introduction to reaction mechanisms, thermodynamic and kinetic data, linear free energy relationships, isotope effects, orbital symmetry.

**CHEM 538. Physical Organic Chemistry II.**

(3-0) Cr. 3. S. *Prereq: CHEM 537*  
Survey of reactive intermediates including cations, anions, carbenes, and radicals.

**CHEM 550. Safety in the Chemical Laboratory.**

(1-0) Cr. 1. S. *Prereq: CHEM 332L*  
Introduction to laboratory safety and chemical hygiene. Use of engineering controls and personal protective equipment. Chemical storage and waste disposal practices. Handling hazardous chemicals. Radiation safety and laser safety. Offered on a satisfactory-fail basis only.

**CHEM 555. Teaching College Chemistry.**

(2-0) Cr. 2. Alt. S., offered 2012. *Prereq: Graduate or senior classification.*  
Methods of instruction, strategies and techniques for effective teaching and learning along with practice teaching in undergraduate chemistry recitation and laboratory courses. Cooperative learning, guided-inquiry, learning cycles, conceptual change, models and modeling, concept maps, visualization, computer simulations, web-based delivery systems, and learning theories.

**CHEM 561. Fundamentals of Quantum Mechanics.**

(4-0) Cr. 4. F. *Prereq: CHEM 324*  
Schrödinger equation and exact solutions; square wells and barriers; harmonic oscillator; the hydrogen atom; atomic orbitals; operators including angular momenta; time-independent and time-dependent perturbation theory; Schrödinger and Heisenberg representations; unitary operators; interaction picture, density matrix.

**CHEM 562. Fundamentals of Atomic and Molecular Quantum Mechanics.**

(3-0) Cr. 3. S. *Prereq: CHEM 561, credit or enrollment in CHEM 583*  
Variational method, many electron atoms; addition of angular momentum, self-consistent field method for open and closed shells, linear combinations of atomic orbitals, origin of chemical bonding, many-electron diatomic and polyatomic molecules, treatments of electron correlation, approximation methods.

**CHEM 563. Statistical Mechanics.**

(3-0) Cr. 3. S. *Prereq: CHEM 325*  
Microscopic and macroscopic properties, laws of thermodynamics, ensembles and distribution functions, applications to gases, solids, and chemical equilibrium.

**CHEM 564. Molecular Spectroscopy and Structure.**

(3-0) Cr. 3. Alt. S., offered 2012. *Prereq: CHEM 505 or CHEM 562*  
Maxwell's field equations, interaction of light with matter including time-dependent perturbation theory, microwave, vibrational (infra-red, Raman) and electronic spectroscopies, symmetry derived selection rules, special lineshapes and introduction to nonlinear and coherent laser spectroscopies.

**CHEM 571. Solid-State Chemistry.**

(2-0) Cr. 2. Alt. S., offered 2013. *Prereq: CHEM 301, CHEM 324*  
A study of solid state materials including structures, bonding, defects, disorder, phase transitions, ionic mobility, metal-insulator transitions, band theory, synthesis and intercalation.

**CHEM 572. Spectrometric Identification of Organic Compounds.**

(2-3) Cr. 3. F. *Prereq: CHEM 332*  
Principles of infrared, ultraviolet, nuclear magnetic resonance, and mass spectroscopy as applied to organic chemistry.

**CHEM 574. Organometallic Chemistry of the Transition Metals.**

(2-0) Cr. 2. Alt. S., offered 2012. *Prereq: CHEM 301, CHEM 332*  
Transition metal complexes of ligands such as cyclopentadienyl, olefins, acetylenes, benzenes, and carbon monoxide. Homogeneous catalysis.

**CHEM 576. Surface Chemistry.**

(3-0) Cr. 3. Alt. F., offered 2012. *Prereq: CHEM 324*  
Gas-surface interactions and techniques of characterization. Idealized surface lattices, surface tension, Wulff plots, work function, adsorbate-adsorbate interactions, 2D phase diagrams, diffusion, thin film growth, adsorption and desorption mechanisms/energetics/kinetics, adsorption isotherms, vacuum techniques, electron- and ion-based spectroscopies for surface analysis (including AES, FIM, XPS, UPS, EXAFS, EELS, SIMS, LEED and STM).

**CHEM 577. Mass Spectrometry.**

(3-0) Cr. 3. S. *Prereq: Permission of instructor*  
Basic physics, instrumentation, chemical and biological applications of mass spectrometry.

**CHEM 578. Chemical Kinetics and Mechanisms.**

(2-0) Cr. 2. Alt. F., offered 2012. *Prereq: CHEM 324*  
Rates and mechanisms; reversible, consecutive, and competing reactions; chain mechanisms; kinetic isotope effects; very rapid reactions; acid-base catalysis, theories of unimolecular reactions; transition state and Marcus theories.

**CHEM 579. Introduction to Research in Chemistry.**

Cr. R. F.  
Introduction to the various areas of research in chemistry at Iowa State University.

**CHEM 580. Introduction to Computational Quantum Chemistry.**

(3-0) Cr. 3. Alt. F., offered 2011. *Prereq: CHEM 324*  
Basic principles of quantum mechanics, Schrödinger equation. Hartree-Fock/molecular orbital theory, introduction to group theory, introduction to modern methods of computational chemistry; applications include molecular structure, potential energy surfaces and their relation to chemical reactions; molecular spectroscopy, photochemistry, solvent effects and surface chemistry.

**CHEM 581. Principles of Lasers and Optics.**

(3-0) Cr. 3. Alt. S., offered 2013. *Prereq: CHEM 324, Phys 222*  
Students with weak background should take Chem 580. For students working with lasers and optics; stimulated adsorption and emission based on the classical electron oscillator model; population inversion, laser amplification; laser pumping; oscillation and cavity modes; laser beam characterization; linear propagation; design of laser resonators, ray and wave optics; nonlinear optics.

**CHEM 583. Chemical Group Theory.**

(1-0) Cr. 1. F. *Prereq: CHEM 324*  
Basic concepts and theorems, representation theory; point groups, molecular orbitals, molecular states, molecular vibrations, rotation group and angular momenta; space groups and crystals; permutation group, antisymmetry, and spin states.

**CHEM 599. Nonthesis Research.**

Cr. arr. *Prereq: Permission of instructor concerned*

**Courses for graduate students:****CHEM 600. Seminar in Inorganic Chemistry.**

(1-0) Cr. 1. Repeatable, maximum of 3 times. F.S. *Prereq: Permission of instructor*

**CHEM 601. Selected Topics in Inorganic Chemistry.**

(2-0) Cr. 1-2. F.S. *Prereq: Permission of instructor*

Topics such as molecular structure and bonding; organometallic compounds; physical techniques of structure determination; nonaqueous solutions; Zintl phases; transition-metal oxides; free-radical reactions; electron transfer reactions; metal-metal bonding; and bioinorganic chemistry of nucleic acids.

**CHEM 611. Seminar in Analytical Chemistry.**

(1-0) Cr. 1. Repeatable. F.S. *Prereq: Permission of instructor*

**CHEM 619. Special Topics in Analytical Chemistry.**

(2-0) Cr. 1-2. Repeatable. F.S. *Prereq: Permission of instructor*

Raman spectroscopy, sensors, spectroelectrochemistry, capillary electrophoresis, analytical plasmas, chemometrics and bioanalytical chemistry.

**CHEM 631. Seminar in Organic Chemistry.**

(1-0) Cr. 1. Repeatable. F.S. *Prereq: Permission of instructor*

**CHEM 632. Selected Topics in Organic Chemistry.**

(2-0) Cr. 1-2. Repeatable. F.S. *Prereq: CHEM 537*

Topics of current interest in organic chemistry such as spectroscopy, physical organic chemistry, photochemistry, organometallic chemistry, mechanisms of oxidations and reductions, modern organic synthesis, reactive intermediates, bioorganic chemistry, and polymers.

**CHEM 660. Seminar in Physical Chemistry.**

(1-0) Cr. 1. Repeatable. S. *Prereq: Permission of instructor*

**CHEM 667. Special Topics in Physical Chemistry.**

(2-0) Cr. 1-2. F.S. *Prereq: Permission of instructor*

Advanced and recent developments in physical chemistry are selected for each offering.

**CHEM 699. Research.**

Cr. arr. Repeatable. *Prereq: Permission of instructor*