

CHEMISTRY (CHEM)

CHEM 100

Introduction to the Profession

Introduction to the chemical sciences, scientific method, computing tools, and interrelations of chemical sciences with biology, physics and other professions.

Lecture: 2 **Lab:** 0 **Credits:** 2

Satisfies: Communications (C)

CHEM 122

Principles of Chemistry I Without Laboratory

An introduction to the foundations of chemistry, including: atoms and molecules; stoichiometry of chemical reactions; thermochemistry; properties of gases; states of matter, chemical solutions; the molecular basis for chemical reactivity; atomic structure; periodicity; and chemical bonding.

Lecture: 3 **Lab:** 0 **Credits:** 3

CHEM 123

General Chemistry Laboratory

General chemistry laboratory. The laboratory portion of CHEM 124.

Prerequisite(s): CHEM 122

Lecture: 0 **Lab:** 3 **Credits:** 1

CHEM 124

Principles of Chemistry I with Laboratory

An introduction to the foundations of chemistry, including: atoms and molecules; stoichiometry of chemical reactions; thermochemistry; properties of gases; states of matter, chemical solutions; the molecular basis for chemical reactivity; atomic structure; periodicity; and chemical bonding.

Lecture: 3 **Lab:** 3 **Credits:** 4

Satisfies: Communications (C)

CHEM 125

Principles of Chemistry II with Laboratory

A continuing introduction to the foundations of chemistry, including: chemical equilibria; the chemistry of acids and bases; solubility and precipitation reactions; kinetics; thermodynamics; electrochemistry; nuclear chemistry; and the basics of organic chemistry.

Prerequisite(s): (CHEM 122 and CHEM 123) or CHEM 124 or IIT Chemistry Placement score of 125

Lecture: 3 **Lab:** 3 **Credits:** 4

Satisfies: Communications (C)

CHEM 126

Principles of Chemistry II Without Laboratory

Same as CHEM 125 except without the laboratory.

Prerequisite(s): (CHEM 122 and CHEM 123) or CHEM 124

Lecture: 3 **Lab:** 0 **Credits:** 3

CHEM 140

Principles of Chemistry II Lab

Laboratory portion of CHEM 125 (Principles of Chemistry II) covering Chemical Equilibria, the chemistry of acids and bases, solubility, and precipitation reactions. Introduction to thermodynamics and electrochemistry. Chemistry of selected elements and their compounds.

Prerequisite(s): CHEM 126

Lecture: 0 **Lab:** 4 **Credits:** 1

CHEM 235

Organic Chemistry I-Lecture

The constitution and properties of the different classes of organic compounds with considerable attention to stereochemistry and reaction mechanisms.

Prerequisite(s): CHEM 125 or CHEM 126

Lecture: 3 **Lab:** 0 **Credits:** 3

CHEM 236

Organic Chemistry I-Lab

Introduction to the major synthetic and analytical techniques of organic chemistry including the preparation of representative organic compounds from natural sources.

Prerequisite(s): CHEM 125 or CHEM 126

Lecture: 0 **Lab:** 4 **Credits:** 1

CHEM 237

Organic Chemistry I

The constitution and properties of the selected classes of organic compounds with considerable attention to stereochemistry and reaction mechanisms. The laboratory work involves the preparation of simple organic compounds using basic synthetic techniques.

Prerequisite(s): CHEM 125 or CHEM 126

Lecture: 3 **Lab:** 4 **Credits:** 4

Satisfies: Communications (C)

CHEM 239

Organic Chemistry II

Sequel to Organic Chemistry I with more emphasis on structure and reactivity of several classes of organic compounds including introductory discussion on common spectroscopic techniques.

Prerequisite(s): CHEM 237 or (CHEM 236 and CHEM 235)

Lecture: 3 **Lab:** 0 **Credits:** 3

CHEM 240

Organic Chemistry Laboratory

Basic techniques for advanced organic preparations. Interpretation of scientific results including percent yield, melting point, boiling point, IR, and NMR spectra.

Prerequisite(s): CHEM 239*, An asterisk (*) designates a course which may be taken concurrently.

Lecture: 1 **Lab:** 4 **Credits:** 2

Satisfies: Communications (C)

CHEM 247**Analytical Chemistry**

This course introduces students to the theory and applications of quantitative analytical chemistry. Topics covered include: statistical data analysis; equilibrium constants expressions; acid-base reactions; volumetric analysis; and fundamentals of spectroscopy, electrochemistry, and of separations science. Laboratory experiments include learning about analytical process, calibration of glassware and equipment, wet chemical analysis, electrochemistry, spectroscopy, and chromatography.

Prerequisite(s): CHEM 125

Lecture: 3 Lab: 3 Credits: 3

Satisfies: Communications (C)

CHEM 321**Instrumental Analysis**

This course introduces students to theory and application of modern instruments in chemical procedures. Standard spectroscopic methods including atomic spectrometry, molecular spectrometry, ultraviolet spectroscopy, molecular luminescence, Fourier transform infrared spectroscopy, and nuclear magnetic resonance spectroscopy. Separation techniques using high pressure liquid chromatography and gas chromatography. Other topics relevant to advanced chemical instrumentation.

Prerequisite(s): CHEM 247

Lecture: 3 Lab: 4 Credits: 4

Satisfies: Communications (C)

CHEM 343**Physical Chemistry I**

Thermodynamic laws and relationships applied to chemical systems. Kinetic theory of gases. Equations of state for ideal and real gases. Calculation of state functions from arbitrary pathways using measurable partial derivatives. Chemical potential and the prediction of phase and reaction equilibria.

Prerequisite(s): (MATH 251 or MATH 252) and CHEM 125

Lecture: 3 Lab: 0 Credits: 3

CHEM 344**Physical Chemistry II**

Introduction to quantum mechanics. Applying quantum mechanics to chemical systems. Atomic structure and spectra. Molecular structure and spectroscopy. Statistical mechanics. Chemical kinetics. The laboratory will include experiments dealing with thermochemistry, phase equilibria, chemical kinetics, spectra, molecular structure, and treatment of data.

Prerequisite(s): (CHE 202 or CHEM 247) and CHEM 343 and MATH 252 and PHYS 221

Lecture: 3 Lab: 4 Credits: 4

Satisfies: Communications (C)

CHEM 410**Science of Climate Change**

This course will focus on the science underlying global warming/ climate change. How can we continue to lead the good life while living in harmony with nature? Although obviously important, commercial/political aspects are not considered here. However, any serious debate about climate change issues eventually has to rest on the underlying scientific facts so we need to be informed. Ultimately the sun is our primary source of power. How do we responsibly access that power in the short, intermediate and long terms? Bio-fuels, carbon dioxide, polar ice caps, and solar power are some of the topics to be discussed. Class time will be divided between lectures and recitation. Permission of instructor required.

Prerequisite(s): CHEM 124 or PHYS 221

Lecture: 3 Lab: 0 Credits: 3

CHEM 415**Inorganic Chemistry**

In-depth introduction to the vast subfield of the discipline dealing with all of the elements in the periodic table. Presents balanced blend of facts and theories in modern inorganic chemistry. Emphasis is on bonding, electronic, magnetic, and structural features exhibited by inorganic and organometallic compounds and their reactivities. Modern concepts including symmetry and group theory and their relevance in solving chemical problems. Bioinorganic chemistry and high tech inorganic materials and solids are introduced.

Prerequisite(s): CHEM 239 or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

CHEM 416**Advanced Chemistry Laboratory**

This advanced laboratory emphasizes chemical synthesis and characterization of inorganic and organometallic compounds. Air and moisture-sensitive techniques are introduced and employed. The synthesis and characterization of nanomaterials is also featured.

Prerequisite(s): (CHEM 240 and CHEM 415*) or Graduate standing, An asterisk (*) designates a course which may be taken concurrently.

Lecture: 1 Lab: 7 Credits: 3

Satisfies: Communications (C)

CHEM 434**Spectroscopic Methods in Identification and Analysis**

Characterization and analysis by mass, vibrational, nuclear magnetic resonance, and electronic spectroscopy. Structure-spectra correlations applied to organic and inorganic compounds with examples drawn from diverse areas, e.g., pollutants, toxic materials, polymers, etc. The laboratory work includes characterization of prepared or separated organic compounds by chromatographic, chemical, and spectroscopic methods.

Prerequisite(s): CHEM 247 and CHEM 240

Lecture: 3 Lab: 4 Credits: 4

CHEM 438**Physical Biochemistry**

The principles and techniques of thermodynamics, kinetics and spectroscopy applied to biological macromolecules will be introduced. Contents to be covered include: interpretation of entropy and enthalpy driven processes, intra- and intermolecular interactions, biochemical equilibrium, free energy driven protein and ion transport, DNA and protein stability, derivation of rate of reaction from reaction mechanism, enzyme kinetics, and principles and applications of spectroscopy in identifying the structures of proteins and nucleic acids.

Prerequisite(s): (CHEM 239 and CHEM 343) or Graduate standing

Lecture: 3 **Lab:** 0 **Credits:** 3

CHEM 450**Introduction to Research**

Designed to give research experience in a faculty research laboratory.

Lecture: 0 **Lab:** 8 **Credits:** 3

Satisfies: Communications (C)

CHEM 451**Undergraduate Seminar**

An overview of a variety of chemical information tools and major scientific databases for navigating primary scientific literature.

There will be a focus on the written and oral presentation of scientific research and the critical evaluation of the same types of scientific communication. Professional development with discussions of behavior, ethics, and career paths.

Prerequisite(s): CHEM 125

Lecture: 3 **Lab:** 0 **Credits:** 3

CHEM 452**Cheminformatics**

This course provides an introduction to chemical informatics and an overview of computer technology and computational methods for search, visualization, analysis, management, and mining of chemical and biochemical data and information. Potential topics include: representation of 2D and 3D chemical structures and chemical reactions; molecular coding; chemical structure database; chemical data and structure descriptors; data visualization and non-linear mapping; database design and management; chemical and biological data analysis and mining; cluster and diversity analysis; and software design and programming; cheminformatics in chemical reaction and property, analytical chemistry, and spectral analysis.

Prerequisite(s): CHEM 343 and CHEM 237

Lecture: 3 **Lab:** 0 **Credits:** 3

CHEM 454**Computational Quantum Chemistry**

A project-based introduction to modern quantum chemistry tools and approaches. Basics of quantum mechanics and Perturbation Theory. Self-Consistent Field Approximation (Hartree-Fock and density functional approximations, post-HF-methods). Concept of orbital interactions (perturbational MO theory: intermolecular perturbations, constructing MO from fragment orbitals). Electronegativity and geometry perturbations. Walsh Diagrams. First and second order Jahn-Teller effects. Analysis of chemical reactivity, clarification of reaction mechanisms, and predicting physical properties associated with molecules. This course will include laboratory work.

Prerequisite(s): (CS 105 and MATH 152 and CHEM 344) or Graduate standing

Lecture: 3 **Lab:** 0 **Credits:** 3

CHEM 455**Advanced Organic Chemistry**

This course provides knowledge on classical and modern organic chemistry at the advanced undergraduate and graduate level. Mechanism and theory of organic reactions, synthetic methodology, and total synthesis will be covered.

Prerequisite(s): CHEM 239 or Graduate standing

Lecture: 3 **Lab:** 0 **Credits:** 3

CHEM 456**Computational Biochemistry and Drug Design**

A project-based introduction to computer-aided drug design tools and the principles behind them. Molecular docking and molecular mechanics force fields for binding enthalpies. Continuum dielectric models of electrostatics and solvation. The Boltzmann distribution and alchemical binding free energy calculations. Quantitative structure property relationships, including for activity and membrane permeability. This course will include laboratory work.

Prerequisite(s): CHEM 343 and CHEM 237

Lecture: 3 **Lab:** 0 **Credits:** 3

CHEM 460**Bioanalytical Chemistry**

This course will provide an introduction to analysis of biomolecules and biologically active molecules and cover analytical and spectroscopic methods for characterization, separation, and detection of biomolecules and biologically active molecules. Students will learn chemical, biochemical, biophysical, chromatographic, electrochemical, and instrumental techniques for detection, qualitative and quantitative analysis, and characterization of small drugs, biomolecules, bioconjugates, biosimilars, and biopharmaceuticals including protein, antibodies, nucleic acid, and enzymes. Potential topics includes acid-base chemistry, chemical kinetics and thermodynamics, biomolecular structure, enzyme and protein chemistry, bioconjugate chemistry, spectroscopy, mass spectrometry, fluorescence microscopy, chromatography, electrochemistry, and analysis and characterization of proteins and nucleic acids.

Prerequisite(s): CHEM 237 and CHEM 343 and CHEM 247

Lecture: 3 **Lab:** 0 **Credits:** 3

CHEM 461**Bioanalytical Chemistry Laboratory**

In this laboratory course of bioanalytical chemistry, students will learn chemical, biochemical, and instrumental lab techniques for detection, analysis, separation, and characterization of small drugs, bioactive agents, and biomolecules. Students will gain hands-on lab experience in the biochemical assays, microscopic, and spectroscopic analysis of biologically active molecules including small drugs, proteins, and DNAs. Potential topics include instrumental and spectroscopic analysis using FTIR, Raman, UV-visible, fluorescence, NMR, AFM, ICP, HPLC, calorimetry, fluorescence microscope, and mass spectrometry; DNA and protein electrophoresis; chromatographic separation; immunoassay; DNA profiling; peptide sequencing; PCR; centrifugation; and microdialysis; and statistical analysis.

Prerequisite(s): CHEM 237 and CHEM 343 and CHEM 247

Lecture: 1 Lab: 7 Credits: 3

CHEM 463**Analytical Method Development Laboratory**

In this laboratory course, students will learn about method development and assessment for analysis of chemicals, organic compounds, polymers, drugs, pharmaceuticals, and biopharmaceuticals. Students will gain hands-on experience in quantitative analysis and quality assurance and control of diverse chemicals and bioactive agents. This course will foster students to develop quantitative and technical analysis techniques, literature comprehension, critical thinking, problem-solving, and communication skills. The literature and guidance on analytical method development and validation reported by the industry and government agencies will be studied. Potential topics include: analytical separation; instrumental analysis; chromatographic and electrophoretic methods; quality assurance and control; analytical method validation; sampling, preparations and storage of samples and standard solutions; physicochemical characterization; statistical analysis; good laboratory practice (GLP) requirement; and validation, verification, and documentation of analytical testing methods and procedure.

Prerequisite(s): CHEM 237 and CHEM 343 and CHEM 247

Lecture: 1 Lab: 7 Credits: 3

CHEM 467**Medicinal Chemistry**

This course will provide an introduction to medicinal chemistry. Potential topics include organic chemistry in drug design and drug action; structure-activity relationship (SAR); mechanism of drug action; pharmaceutical analysis and formulation; binding affinity, selectivity, and specificity; drug efficacy, toxicity, and oral bioavailability; drug absorption, distribution, metabolism and excretion (ADME); pharmacokinetics (PK); pharmacodynamics (PD); interaction of drugs with enzymes, protein receptors, DNAs, and RNAs; protein-protein interaction; enzyme inhibition and mechanism; molecular target identification and detection; prodrugs; biologics; antibody-drug conjugate (ADC) chemistry; drug discovery process; development of therapeutics, diagnostics, and theranostics; pharmaceutical and clinical data analysis; case studies of preclinical and clinical trials.

Prerequisite(s): CHEM 343 and CHEM 239

Lecture: 3 Lab: 0 Credits: 3

CHEM 470**Introduction to Polymers**

Introductory course covering fundamental aspects of polymers with major emphasis on synthesis, polymerization mechanisms, chain architecture, relationship between polymer structures and properties, measurement and control of molecular weights, thermal and mechanical properties, and polymer processing.

Prerequisite(s): CHEM 239 or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

CHEM 472**Environmental Chemistry**

This course provides an introduction to environmental chemistry and is focused on application of chemical principles and theories to the study of environmental phenomena and issues and covers matters related to environment and earth. Potential topics include aquatic chemistry, water pollution and purification, atmospheric chemistry, air pollution, hydrology and geochemistry, soil chemistry and pollution, natural resource and cycle, energy and sustainability, climate change, chemical bonding and reactions, thermodynamics and kinetics, acid-base chemistry, redox chemistry, bio-inorganic chemistry on earth and living systems, organic and inorganic toxicants and pollutants, hazardous heavy metals, nuclear wastes, waste and recycling, green chemistry, environmental toxicology, and chemical and environmental health and safety.

Prerequisite(s): (CHEM 125 or CHEM 126) and CHEM 247

Lecture: 3 Lab: 0 Credits: 3

CHEM 473**Environmental Analytical Chemistry**

This course provides an overview of applications of analytical chemistry to environment and environmental problems. Students will learn spectrometric, chromatographic, electrochemical measurement methods and concepts for analysis of environmental samples and tracing and monitoring of environmental problems. Potential topics include: quality assurance (QA) and quality control (QC) in environmental sampling and analysis; determination of trace elements, toxicants, organics, pollutants, heavy metals, and radionuclides in environmental samples and drinking water; analytical tools for tracing and monitoring of pollution and contamination; instrumental analysis of environmental samples using ICP-MS (inductively coupled plasma-mass spectrometry), ICP-AAS (atomic absorption spectroscopy), ICP-AES (atomic emission spectrometry), ion chromatography, and gas chromatography (GC), GC-MS, high performance liquid chromatography (HPLC); chemometrics; electrochemical methods; GC/LC separation methods, liquid-liquid and solid phase extraction; statistical data analysis.

Prerequisite(s): (CHEM 125 or CHEM 126) and CHEM 247

Lecture: 3 Lab: 0 Credits: 3

CHEM 475**Forensic Chemistry**

This course will provide an introduction to forensic chemistry and prepare students to build a sound knowledge in chemical, biochemical, and instrumental methods for forensic analysis and statistical analysis of forensic data. The class will cover principles and applications of chemical, biochemical, spectroscopic, and chromatographic methods for analysis and characterization of forensic samples. Potential topics include forensic applications of UV-Visible, IR, Raman, NMR, atomic absorption (AA) spectroscopy, fluorescence microscopy, X-ray, mass spectrometry; chromatographic methods (GC, HPLC, and TLC) and capillary electrophoresis for separation of forensics; analysis and identification of enforced drugs; colorimetric methods; microscopy and immunoassays for forensic examination; chemistry in examination and analysis of chemical, biological, and physical forensic samples (alcohol, carbon monoxide, papers, hair, gunpowder, inks, fibers, paints, firearms, fingerprint, palmprint, documents, and body fluid and blood samples); crime lab services; forensic statistics; introduction to international forensic databases.

Prerequisite(s): CHEM 237 and CHEM 343 and CHEM 247

Lecture: 3 Lab: 0 Credits: 3

CHEM 476**Forensic Chemistry Laboratory**

This lab course will cover chemical, spectroscopic, and chromatographic methods for analysis and characterization of forensic samples. Students will gain hands-on lab experience in instrumental, colorimetric, and microscopic analysis of forensic samples, controlled substances, and standards. Potential topics include: colorimetric assay for identification and quantification of illicit drugs; fingerprint chemistry; IR, Raman, Fluorescence, and NMR-based spectroscopic analysis of controlled substances, forensic samples, and gold standards; GC-MS, HPLC, and TLC for detection and separation of forensic samples; spot testing and microscopic analysis and characterization of biologic fluids and forensic samples; construction of calibration curves; analysis of forensic samples using an international database including paint data query (PDQ), NIST's Forensic database trace evidence table, international ink library, glass evidence reference; introduction to visualization software.

Prerequisite(s): CHEM 237 and CHEM 343 and CHEM 247

Lecture: 1 Lab: 7 Credits: 3

CHEM 485**Chemistry Colloquium**

Lectures by prominent scientists. This course exposes students to current and active research in chemistry both within and outside the IIT community. It helps prepare students for a career in research. It is complementary to the academic courses and provides examples of professional/scientific presentations. This course may not be used to satisfy the natural science general education requirement.

Prerequisite(s): CHEM 239

Lecture: 0 Lab: 1 Credits: 1

CHEM 487**Senior Thesis in Chemistry**

Original work carried on by the student under the guidance of a staff member. A careful search of the literature is required before the study is begun, and continued reference to the chemical literature is expected as the work progresses. A written report is required.

Prerequisite(s): CHEM 450

Lecture: 0 Lab: 12 Credits: 4

Satisfies: Communications (C)

CHEM 491**Undergraduate Research**

Student participation in undergraduate research, usually during the junior or senior year.

Credit: Variable

Satisfies: Communications (C)

CHEM 495**Seminar in Special Topics**

This seminar course is designed to provide students with opportunities to learn about recent development in specialized chemistry areas including bioanalytical chemistry, environmental chemistry, forensic chemistry, medicinal chemistry, and computational chemistry and biochemistry. Students are expected to develop written and oral communication skills on the advanced and specialized topics. Prerequisites or Instructor Approval.

Prerequisite(s): CHEM 125 or CHEM 126

Lecture: 1 Lab: 0 Credits: 1

CHEM 497**Special Projects**

For juniors and seniors.

Credit: Variable

Satisfies: Communications (C)

CHEM 500**Advanced Analytical Chemistry**

An overview of analytical chemistry with discussions of complex ionic equilibria, electro analytical techniques including potentiometric, voltametric, coulometric and conductometric methods, ion chromatography, capillary electrophoresis and sensor technology.

Lecture: 3 Lab: 0 Credits: 3

CHEM 501**Capstone Project**

This course will educate students in the area of quality process and quality manufacturing. Student will work with the instructor to plan and conduct research on a project that is relevant to the analytical chemistry program of study. The project must be approved by the Master of Chemistry in Analytical Program Director.

Lecture: 1 Lab: 3 Credits: 2

CHEM 503**Survey of Analytical Chemistry**

This course covers modern aspects of chemical analysis. It is designed to give the student a solid conceptual ground to understand how a given analytical technique works including its limits and advantages. The emphasis is on solutions analysis and the course is roughly divided into: (i) Basic measurements and concepts; (ii) spectroscopy; and (iii) chromatography and mass spectrometry. Upon completion of this course, the student will be able to: describe the basic setup and operation of separation, mass spectrometric, and spectroscopic instrumentation; interpret spectra from various instruments as a means for qualitative and quantitative analysis; apply basic knowledge of separation technique, mass spectrometry, and spectroscopy for practical problem solving; relate the use of separation technique, mass spectrometry, and spectroscopy to his or her own research interests; and compile, present, and explain modern techniques for analytical research. Topics includes high-performance liquid chromatography, gas chromatography, atomic spectrometry, molecular spectrometry, UV/vis spectroscopy, molecular luminescence, infrared spectrometry, mass spectrometry, radio chemistry, raman spectroscopy, nuclear magnetic resonance spectroscopy, etc.

Lecture: 3 Lab: 0 Credits: 3

CHEM 505**Spectroscopic Methods I**

Theories of spectroscopic transitions and their applications in structural elucidations and quantitative analysis. Topics include ultraviolet/visible, infrared, Raman and nuclear magnetic resonance spectroscopy and mass spectrometry.

Lecture: 3 Lab: 0 Credits: 3

CHEM 506**Sampling and Sample Preparation**

Techniques and devices for sampling in diverse media will be treated, followed by a discussion of sample treatment prior to analysis including isolation, concentration, and fractionation of analytes and classes of analytes.

Lecture: 3 Lab: 0 Credits: 3

CHEM 508**Analytical Methods Development**

A seminar course presenting analytical methods in complex matrices with emphasis on methods development and validation.

Lecture: 2 Lab: 0 Credits: 2

CHEM 509**Physical Methods of Characterization**

A survey of physical methods of characterization including x-ray diffraction and fluorescence surface techniques including SEM, TEM, AES and ESCA, thermal methods and synchrotron radiation methods.

Lecture: 3 Lab: 0 Credits: 3

CHEM 510**Electronics and Interfacing**

Elementary circuit analysis, operational amplifiers, digital electronics, signal processing and interfacing of instruments using modern computer software and hardware.

Lecture: 2 Lab: 0 Credits: 2

CHEM 512**Spectroscopic Methods II**

A continuation of the study of optical methods covering atomic absorption spectroscopy, atomic and flame emission spectroscopy, chemiluminescence, fluorescence, phosphorescence, light scattering and refractometry.

Lecture: 2 Lab: 0 Credits: 2

CHEM 513**Chemometrics and Statistics in Chemistry**

This course is carefully designed to provide a vigorous training on statistical methods to graduate students and industry professionals for analysis of real life projects so they can function effectively as part of an innovative and scientific community. The topics include, but not limited to, advanced error analysis, statistical inference, hypothesis testing, probability density functions, sampling estimation, applied regression and multivariable methods, non-parametric analysis, outlier identification methods, and optimization and experimental design. In this course, an advanced statistical software program is introduced with example problems for comprehensive analysis of data and interpretation of the results. The course also discusses various topics for scientific interpretation of data set for chemical, environmental, and biological engineering disciplines.

Lecture: 3 Lab: 0 Credits: 3

CHEM 515**Gas Chromatography -- Theory and Practice**

This course will cover theory and concepts of gas chromatographic analysis and its practical application in solving analytical problems. Topics include basic theory of chromatographic separation, separation dynamics, instrumentation, column selection, quantitative techniques, and practical applications.

Lecture: 3 Lab: 0 Credits: 3

CHEM 516**Liquid Chromatography -- Theory and Practice**

This course will cover the operating principles and applications of state-of-the-art LC/HPLC instrumentation and analysis. Topics include basic theory of liquid chromatography, instrumentation, optimization of LC separation, quantitative techniques, and the diverse range of analytical applications amenable to LC analysis.

Prerequisite(s): CHEM 515 with min. grade of C

Lecture: 3 Lab: 0 Credits: 3

CHEM 518**Understanding the International Conference on Harmonization Guidelines**

The International Conference on Harmonization (ICH) was revolutionized in the 1980's to provide a forum for the pharmaceutical industry to discuss regulatory requirements for registration of new chemical entity. These guidelines have been significantly influenced the content of FDA draft guidelines to develop the scientific information and manufacturing controls. Thus, proper understanding of these guidelines is essential in the drug development process. This course will be designed to focus exclusively on guidelines associated with the registration of small molecules. Completing this course, students will understand the expectations set forth in various FDA and ICH quality topics in order to implement these guidelines and/or engage the regulatory agencies in dialogue in order to provide justification of data or present clear scientific rationale.

Lecture: 3 Lab: 0 Credits: 3

CHEM 519**Good Manufacturing Practices**

This course provides an introduction to current good manufacturing practices (GMP) regulations and their implementation to different areas of the manufacturing process such as laboratory records, equipment, personnel, facilities, etc. The course will help students to recognize the regulatory actions and financial risks for non-compliance.

Lecture: 3 Lab: 0 Credits: 3

CHEM 520**Advanced Inorganic Chemistry**

Selective treatment of the chemistries of main group and transition elements with emphasis on coordination complexes, organometallic compounds and inorganic cages and clusters. Discussions of molecular symmetry, stereochemistry, bonding, electronic spectra, magnetic properties, reactions, kinetics and reaction mechanisms are included.

Lecture: 3 Lab: 0 Credits: 3

CHEM 521**Structural Inorganic and Materials Chemistry**

This course covers structure and bonding and structure-property relationships in inorganic molecules and solids. Descriptions of crystal structures, spectroscopic and x-ray diffraction techniques for structure determination and properties of solids are included.

Lecture: 3 Lab: 0 Credits: 3

CHEM 522**Efficient Chemical and Materials Synthesis**

The design and development of environmentally benign chemical pathways: challenges and opportunities. High-yield and zero-waste chemical processes. Representative processes.

Lecture: 3 Lab: 0 Credits: 3

CHEM 524**Synthesis and Intellectual Property Management**

This course focuses on the management of intellectual property. Professionals will lead discussions on the control and dissemination of materials concerning intellectual property. This will be combined with the technical presentations by the students in the classroom. Topics of discussion will include invention disclosures, intellectual property rights, proprietary materials, justification for patents, types of patents, the terms of a patent, patents procedure, licensing procedure and security considerations. Access to patented materials and disclosure of materials under patent process will be covered.

Lecture: 2 Lab: 0 Credits: 2

CHEM 526**Graduate Chemistry Laboratory**

An advanced laboratory with emphasis on synthesis and characterization of inorganic and organometallic compounds.

Lecture: 1 Lab: 7 Credits: 3

CHEM 530**Organic Reaction Mechanisms**

A study of important mechanism classes and their relationship to the major reactions of organic chemistry. Emphasis will be placed on the study of reaction intermediates and on the methods used to characterize reaction pathways. Topics will include chemical bonding, aromaticity, stereochemistry, substitution, elimination, carbanion chemistry, free radical reactions, photochemistry and concerted reactions.

Prerequisite(s): CHEM 455 with min. grade of C

Lecture: 3 Lab: 0 Credits: 3

CHEM 531**Tactics in Organic Synthesis**

A study of modern synthetic strategies used in the preparation of complex organic molecules. Synthetic planning using the disconnection approach and the selection of reagents to solve regiochemical and stereochemical problems will be the underlying themes. Synthetic strategies to be discussed include tandem reactions, template and chelation effects, biomimetic tactics and the use of chiral terpenes, carbohydrates and amino acids in enantioselective syntheses. Target molecules will include natural products, pharmaceuticals and smart organic materials.

Prerequisite(s): CHEM 530 with min. grade of C

Lecture: 3 Lab: 0 Credits: 3

CHEM 534**Advanced Spectroscopic Methods**

Characterization and analysis by mass, vibrational, nuclear magnetic resonance, and electronic spectroscopy. Structure spectra correlations applied to organic and inorganic compounds with examples drawn from diverse areas, e.g., pollutants, toxic materials, polymers, etc.

Lecture: 3 Lab: 4 Credits: 4

CHEM 535**Polymer Synthesis**

This course will cover the basics of polymer synthesis including traditional polymerization techniques, such as free-radical and ionic chain polymerizations, and step-growth polymerization. Newer methods of polymer synthesis, such as ring-opening metathesis and controlled free-radical polymerizations, will also be discussed. Students will be introduced to the methods of preparation of advanced polymer structures, such as block, star and brush copolymers, dendrimers, and hyperbranched polymers.

Prerequisite(s): CHEM 239 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

CHEM 537**Polymer Chemistry Laboratory**

This course will include the synthesis of a variety of polymers and their characterization using instrumental methods. Emphasis will be placed on factors that control polymer formation, methods for obtaining molecular weights and distributions of polymers, as well as thermal and mechanical characteristics of polymers.

Prerequisite(s): CHEM 470 with min. grade of C

Lecture: 1 Lab: 6 Credits: 3

CHEM 538**Physical Biochemistry**

The course will cover the principles and techniques of physical chemistry applied to biological macromolecules. Topical concepts include thermodynamics, kinetics, and quantum chemistry. Applications to areas such as interpretation of entropy and enthalpy driven processes, biochemical equilibrium, phase transitions in lipid, bilayers and membranes, enzyme kinetics, intra- and intermolecular interactions, and spectroscopy of proteins and nucleic acids will be introduced.

Prerequisite(s): (CHEM 239 with min. grade of C and CHEM 344 with min. grade of C) or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

CHEM 539**Introduction to Pharmaceutical Chemistry**

Fundamental concepts will be discussed, including modern principles of drug design; drug absorption, distribution and metabolism; theories of drug-receptor interactions; approaches to structure-activity relationships; chemical, physicochemical and structural considerations. The various classes of therapeutic agents will be surveyed with emphasis on possible modes of action. Methods of synthesis will be considered.

Prerequisite(s): CHEM 239 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

CHEM 542**Polymer Characterization and Analysis**

This course will provide an overview of the common techniques for polymer characterization, studying structure-property relationships, and polymer morphology. The course will focus on thermal and mechanical characterization of polymers as well as polymer rheology. Examples and uses of major commercial polymers and advanced functional polymers will be introduced.

Lecture: 3 Lab: 0 Credits: 3

CHEM 543**Analytical Chemistry in Pharmaceutical Laboratories**

This course is designed to compliment the current curriculum of the professional master degree in analytical chemistry. It is a review of the requirements a student may face as a professional chemist in a regulated industry. The course focus is on the requirements and common topics facing today's pharmaceutical industry. While individual agencies have specific regulations, the fundamental ideas of these regulations are largely consistent across the board. For example, an analytical chemist versed in Good Laboratory Practices (GLP) under FDA can quickly pick up the GLP's required by EPA.

Lecture: 2 Lab: 0 Credits: 2

CHEM 544**Colloids and Colloid Analysis**

This course will begin a general overview of colloid science. This part of the course will introduce various types of colloids, touch on factors and conditions leading to their stability or instability, consider their evolution and will include a very limited discussion of the conditions under which they can form. The second part of the course will consist of a series of discussions of specific analytical techniques used to characterize colloidal systems, with particular emphasis on the physical characterization of the dispersed phase.

Lecture: 2 Lab: 0 Credits: 2

CHEM 545**Sensor Science and Technology**

This course is designed for students to attain a broad and in-depth acquaintance with the mechanism, platform and targets of various sensors, with a focus on chemical sensors and biosensors. Topical concepts covered include: sensor components and characteristics; synthetic, biological and biomimetic materials used in sensor development; miniaturization and nanotechnology involved in sensor fabrication; various sensing modalities, data analysis and device prototyping. Students will be required to partner with others and consult with academic and industrial scientists to design sensors of their own interests as a final project for assessment. The course is intended for graduate students and senior undergraduate students.

Lecture: 3 Lab: 0 Credits: 3

CHEM 546**Project in Sensor Science and Technology**

This course is designed to offer students the opportunity of hands-on sensor research. It can be in the form of a research project in a sensor research group, a joint project between different sensor research groups, or an internship project in industry.

Prerequisite(s): CHEM 545*, An asterisk (*) designates a course which may be taken concurrently.

Lecture: 0 Lab: 9 Credits: 3

CHEM 548**Electrochemical Methods**

Thermodynamics and potential, charge-transfer kinetics and mass transfer. Potential step and potential sweep methods, including hydrodynamic methods. Bulk electrolysis methods. Electrode reactions coupled with homogeneous chemical reactions. Double-layer structure and adsorbed intermediates in electrode processes. Digital simulation of electrochemical processes. Students are expected to have some background in the physical chemistry of solutions and electroanalytical chemistry at the level of CHEM 500.

Lecture: 3 Lab: 0 Credits: 3

CHEM 550**Theoretical and Computational Quantum Chemistry**

An overview of quantum chemistry ranging from foundational postulates and analytical systems to approximation methods and practical molecular modeling calculations. Postulates of quantum mechanics and applications to model systems relevant to chemistry including the particle in a box, harmonic oscillator, rigid rotor, and hydrogen atom. Approximation methods based on perturbation theory and the variational principle. Principles of computational techniques including basis sets and the Hartree-Fock method. Molecular modeling calculations including geometry optimization, electron density, electrostatic potential, and spectroscopy predictions.

Prerequisite(s): (CS 105 and MATH 252 and CHEM 344) or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

CHEM 552**Chemical Kinetics**

Types of reactions, reaction order, activation energy, transition states, isotope effects and the mechanism of reactions. Determination of the rates of free radical reactions. Primary processes in thermal, photochemical and other radiation-induced reactions.

Prerequisite(s): CHEM 553 with min. grade of C and CHEM 550 with min. grade of C

Lecture: 3 Lab: 0 Credits: 3

CHEM 553**Chemical Statistical Thermodynamics and Molecular Simulation**

Statistical interpretation of the fundamental properties and laws of thermodynamics. Ensembles, partition functions, and principles of molecular simulation. Applications to chemical and phase equilibria including case studies from contemporary literature.

Prerequisite(s): (CHEM 343 with min. grade of C and CHEM 344 with min. grade of C) or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

CHEM 560**Advanced Chemistry Projects**

Advanced chemistry projects to be carried out under the direction of a faculty member. These projects may involve computational, theoretical, experimental work or a combination of these. Projects based on experimental work may be carried out in the research lab of the instructor. Topics of the advanced projects will be selected by the faculty member offering the course and will not necessarily be related to the dissertation topic of the student. May be taken more than once and up to 12 credit hours.

Credit: Variable

CHEM 561**Laboratory Rotations**

This course requires each student to complete research rotations in three different laboratories, 4 weeks in each lab. It allows students to explore various areas of chemical research before committing to a single lab to conduct thesis research. The course intends to give students an opportunity to learn what research topics excite them, what techniques they favor and what lab environment is a good fit. At the same time, rotations provide faculty the mechanism for evaluating students as candidates to join their lab. Submission of a report is required upon the completion of each rotation.

Lecture: 0 Lab: 9 Credits: 3

CHEM 584**Graduate Seminar in Chemistry**

To foster scientific communications skills, students are required to present seminars based on the scientific literature. Required of all first year M.S. and PhD students.

Lecture: 0 Lab: 1 Credits: 1

CHEM 585**Chemistry Colloquium**

Lectures by invited scientists in areas of chemistry generally not covered in the department. Must be taken two time by M.S. students and four time by PhD. students.

Lecture: 0 Lab: 1 Credits: 1

CHEM 591**Research and Thesis**

(Credit: Variable)

Credit: Variable

CHEM 594**Special Problems**

Designed for non-thesis M.S. only. (Credit: Variable)

Credit: Variable

CHEM 596**Chemistry for Teachers-Elementary**

Certification as chemistry teacher or approval of instructor. An in-service workshop for pre-college teachers emphasizing the phenomenological approach to the teaching of chemical science. (Credit: variable)

Credit: Variable

CHEM 597**Reading and Special Problems**

Independent study to meet the special needs of graduate students in department-approved graduate degree programs. Requires the written consent of the instructor. May be taken more than once. Receives a letter grade. (Credit: Variable)

Credit: Variable

CHEM 598**Chemistry for High School Teachers**

Certification as teacher or approved of instructor. An in-service workshop for pre-college teachers emphasizing the phenomenological approach to teaching of chemical science at the high school level. (Credit: variable)

Credit: Variable

CHEM 600**Continuation of Residence****Lecture: 0 Lab: 0 Credits: 1****CHEM 610****Special Topics in Analytical Chemistry**

Topics of current interest in analytical chemistry including advanced electro-chemistry, surface spectroscopy of electrode surfaces, separations, laboratory automation and new spectroscopic techniques.

Lecture: 2 Lab: 0 Credits: 2**CHEM 611****Special Topics in Analytical Chemistry**

Topics of current interest in analytical chemistry including advanced electro-chemistry, surface spectroscopy of electrode surfaces, separations, laboratory automation and new spectroscopic techniques.

Lecture: 2 Lab: 0 Credits: 2**CHEM 620****Special Topics in Inorganic Chemistry**

Topics of current interest in inorganic chemistry, including organometallic chemistry, homogeneous catalysis, inorganic reaction mechanisms, inorganic stereochemistry, materials chemistry, x-ray crystallography, synthetic and physical methods in inorganic and materials chemistry and chemical applications of group theory.

Lecture: 2 Lab: 0 Credits: 2**CHEM 621****Special Topics in Inorganic Chemistry**

Topics of current interest in inorganic chemistry, including organometallic chemistry, homogeneous catalysis, inorganic reaction mechanisms, inorganic stereochemistry, materials chemistry, x-ray crystallography, synthetic and physical methods in inorganic and materials chemistry and chemical applications of group theory.

Lecture: 2 Lab: 0 Credits: 2**CHEM 630****Special Topics in Organic Chemistry**

Topics of current interest in organic chemistry including photochemistry, fluorine chemistry, heterocyclic chemistry, pharmaceutical chemistry and electro optical organic chemistry.

Prerequisite(s): CHEM 455 with min. grade of C**Lecture: 2 Lab: 0 Credits: 2****CHEM 631****Special Topics in Organic Chemistry**

Topics of current interest in organic chemistry including photochemistry, fluorine chemistry, heterocyclic chemistry, pharmaceutical chemistry and electro optical organic chemistry.

Prerequisite(s): CHEM 455 with min. grade of C**Lecture: 2 Lab: 0 Credits: 2****CHEM 635****Heterocyclic Chemistry**

Of the vast array of structures which organic compounds adopt, many contain ring systems as a component. When the ring is made up of carbon and at least one other element, the compound is classified as a heterocycle. The aims of this course are to identify the effects that the presence of such ring systems have on the chemistry of a molecule; to show how the rings can be made, and to describe some of the uses of the compounds in organic synthesis, in medicine and in other contexts. The chemistry of aromatic five-, six- and seven-membered ring compounds with one or more nitrogen, oxygen and/or sulfur atoms will be emphasized.

Prerequisite(s): (CHEM 239 with min. grade of C and CHEM 455 with min. grade of C) or Graduate standing**Lecture: 3 Lab: 0 Credits: 3****CHEM 650****Special Topics in Physical Chemistry**

Topics of current interest in physical chemistry, including atmospheric chemistry, ion molecule reactions, laser chemistry, theories of gas phase reactions, scattering theory, interaction of radiation with matter and time-dependent relaxation methods.

Lecture: 2 Lab: 0 Credits: 2**CHEM 651****Special Topics in Physical Chemistry**

Topics of current interests in physical chemistry, including atmospheric chemistry, ion molecule reactions, laser chemistry, theories of gas phase reactions, scattering theory, interaction of radiation with matter and time-dependent relaxation methods.

Lecture: 2 Lab: 0 Credits: 2**CHEM 684****Graduate Seminars in Chemistry**

To foster scientific communications skills, students are required to present seminars based on the scientific literature. Required of all Ph.D. students who have passed the written qualifying examination.

Lecture: 1 Lab: 0 Credits: 1**CHEM 685****Chemistry Colloquium**

Lectures by invited scientists in areas of chemistry generally not covered in the department.

Prerequisite(s): CHEM 585 with min. grade of C**Lecture: 0 Lab: 1 Credits: 1****CHEM 691****Research and Thesis Ph.D.**

(Credit: Variable) Instructor permission required.

Credit: Variable**CHEM 700****Practical Laboratory for Analytical Chemistry**

In this one-week intensive course, students will gain hands-on experience using analytical instruments. A brief review of theory of instrumentation will be covered. Students will carry out practical problems and will present their findings.

Lecture: 2 Lab: 4 Credits: 2