There are six core areas. These are:

- analytical chemistry,
- biochemistry,
- environmental chemistry,
- inorganic chemistry,
- organic chemistry, and
- physical chemistry.

Students enrolled in the research/thesis option must take one course from three different core areas; non-thesis option students must take one course from three of the core areas.

**Seminar**
All students are required to register for seminar (CHEM 790, one credit, pass/fail) and attend departmental seminars for one semester.

**Research and Thesis**
During their first semester (and not later than the end of their first academic year), students electing the Research/Thesis Option are required to interview the chemistry graduate faculty, choose a graduate faculty research advisor, and select a research committee in consultation with their advisor and the Graduate Program Director. Upon completion of their research, students must write a formal thesis describing their research, present their work in a public seminar, and pass an oral examination by their research committee.

**Non-Thesis Option**
Not later than the end of their first academic year, students electing the Non-Thesis Option are required to interview the chemistry graduate faculty and choose an independent study advisor. Non-thesis students and their independent study advisor will then agree upon an independent study project. Upon completion of their independent study project, non-thesis students must write a formal Independent Study Report acceptable to their independent study advisor and the Graduate Studies Committee and pass an oral exam on their project.

**Doctor of Philosophy – Chemistry**
The Ph.D. program in Chemistry prepares students in the application of chemical principles to address many of society's technical, environmental, and biomedical problems. Students will be able to provide leadership in industrial, governmental, and educational institutions in directing research and/or development to solve these problems. The Ph.D. degree is granted to students who have:

1. mastered advanced knowledge of definite sub-fields of chemistry
2. become familiar with research in these specific fields and developed perceptions of opportunities for further scientific advances
3. demonstrated the capacity to perform original, independent, and scholarly scientific investigation in their specific field and interpret their results.

All students admitted to the program must read and understand the regulations and policies described here and elsewhere throughout this catalog relevant to Old Dominion University’s requirements for Ph.D. degrees. The essential credit requirements for the Ph.D. are:

- A minimum of 78 credit hours beyond the Bachelor's degree, and
- 48 credit hours beyond the Master's degree.

**Admission**
An application (http://www.odu.edu/admission), transcripts, three letters of recommendation from former college instructors, an essay about career goals, and Graduate Record Examination (GRE) scores (general only) are required for consideration of admission to the program. Admission to regular status requires a grade point average of 3.00 in the major and 3.00 overall (based on a 4.00 scale). General university admission requirements also apply. In addition, a Bachelor of Science degree (or equivalent) with a major in chemistry (or another science) is required, although applications from majors in all science disciplines are encouraged. Undergraduate courses in organic chemistry, inorganic chemistry, analytical chemistry, materials chemistry, organic chemistry, and physical chemistry.

An application (http://www.odu.edu/admission), transcripts, three letters of recommendation from former college instructors, an essay about career goals, and Graduate Record Examination (GRE) scores (aptitude section) are required for consideration of admission to the program. Admission to regular status requires a grade point average of 3.00 in the major and 3.00 overall (based on a 4.00 scale). General university admission requirements also apply. In addition, a Bachelor of Science degree (or equivalent) with a major in chemistry (or another science) is required, although applications from majors in all science disciplines are encouraged. Undergraduate courses in organic chemistry, inorganic chemistry, analytical chemistry, materials chemistry, organic chemistry, and physical chemistry.

**Program Requirements**

**Writing Proficiency Policy**
The departmental graduate committee will request a writing sample from each new student. The graduate committee will refer students in need of remedial assistance to the Writing Center.

**Options**
Candidates for the master’s degree have two options in their program: the Research/Thesis option and the Non-Thesis option.

**Courses**

<table>
<thead>
<tr>
<th>Course Type</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thesis option</td>
<td>24</td>
</tr>
<tr>
<td>Research and Thesis</td>
<td>6</td>
</tr>
<tr>
<td>Total Hours</td>
<td>30</td>
</tr>
<tr>
<td>Non-thesis option</td>
<td>30</td>
</tr>
<tr>
<td>Independent study</td>
<td>3</td>
</tr>
<tr>
<td>Total Hours</td>
<td>33</td>
</tr>
</tbody>
</table>

Up to 15 hours may be taken in related courses given by other departments pending approval from the Graduate Studies Committee of the Department of Chemistry and Biochemistry. At least 60 percent of the credit hours must be from 600-level courses or higher.

Students who earn a grade of less than a B- in any two graduate courses will not be allowed to continue in the M.S. program.

**Core Courses**
There are six core areas. These are:
Program Requirements

Writing Proficiency Policy

The departmental graduate committee will request a writing sample from each new student. If the graduate committee feels that remedial assistance in writing is needed, the student will be referred to the Writing Center.

Courses

A minimum of 78 semester hours beyond the undergraduate degree or 48 hours past the master's degree is required by this program. The broad requirements for granting the Ph.D. are as follows:

- satisfactory performance in core and elective courses,
- successful completion of both written and oral portions of the Candidacy Examination,
- completion of the dissertation prospectus,
- and completion of a satisfactory dissertation and defense of the dissertation.

Students who earn a grade of less than a B- in any two graduate courses will not be allowed to continue in the Ph.D. program.

Core Courses

Students must choose one course from three different core areas. The core areas are:

- analytical chemistry,
- biochemistry,
- environmental chemistry,
- inorganic chemistry,
- organic chemistry, and
- physical chemistry.

Classes from each area are listed on the following pages.

Elective Courses

Students are required to take nine credit hours of elective courses. The courses are to be chosen upon consultation with their advisor and/or their guidance committee.

Teaching

Students are required to spend at least one semester as a teaching assistant.

Seminar

All students are required to register for seminar CHEM 890 (one credit, graded pass/fail) and attend departmental seminars throughout their graduate career. Twice during their career, students will register for CHEM 891 (two credits) and present a seminar, which will receive a letter grade. In the second year, students will give a background literature talk on their research. The second semester of CHEM 891 may not be taken in the same semester as graduation.

Advisor Selection

During their first semester (and not later than the end of their first semester), students are required to interview the chemistry graduate faculty (a signed sheet of at least three faculty members is required), choose a graduate faculty research advisor, and select a guidance committee in consultation with their advisor and the Graduate Program Director.

Candidacy Examination

A student enrolled in the Ph.D. program in chemistry becomes a candidate for the doctoral degree by passing the Ph.D. candidacy examination. This examination consists of a written portion and oral portion. The student is required to submit a written description of a novel research idea in the form of a grant proposal, and then present and defend the idea to his or her guidance committee.

Dissertation

The dissertation is the final and most important part of the work required for the Ph.D. degree. The dissertation must be based on original research and make a contribution to existing knowledge of sufficient interest to warrant publication in a refereed journal. The candidate normally works closely with the research advisor, who is chair of the dissertation committee.

Dissertation Defense

The final examination of the candidate consists of the oral defense of the dissertation. This public examination is conducted by the dissertation committee with the research advisor serving as chair.

Doctor of Philosophy - Biomedical Sciences

Robert E. Ratzlaff, Graduate Program Director

In this interdisciplinary program all students are required to master a broad knowledge of the basic biomedical sciences. Refer to the College of Sciences (http://catalog.odu.edu/graduate/collegeofsciences) section of this catalog for details.

CHEMISTRY AND BIOCHEMISTRY Courses

CHEM 511. Natural Products Chemistry in the Caribbean. 4 Credits.
A bioorganic and natural products course that entails the chemistry of the use of chromium, vanadium, and herbs in medicine and the use of tunicates as biomonitor of heavy metal pollution in Jamaica. This is a study abroad course intended for the Maymester term. Prerequisites: CHEM 211 and CHEM 212 with a C or better.

CHEM 515. Intermediate Organic Chemistry. 3 Credits.
An in-depth look at organic reaction mechanisms, including polar, pericyclic, radical and organometallic reactions.

CHEM 521. Instrumental Analysis Lecture. 3 Credits.
Designed to be taken concurrently with CHEM 522. A study of the basic principles of spectroscopic, chromatographic, and electrochemical methods of quantitative chemical analysis. Methods of chemical instrumentation are also included.

CHEM 522. Instrumental Analysis Laboratory. 3 Credits.
An intensive laboratory study of the principles of analytical chemistry. Experiments in spectroscopic, chromatographic, and electrochemical methods are conducted to illustrate fundamental principles and to provide the opportunity to develop skills in the use of instrumentation for chemical measurement. Pre- or corequisite: CHEM 521 with a grade of C or better.

CHEM 539. Introduction to Pharmaceutical Chemistry. 3 Credits.
An introduction to the fundamental concepts of drug action including pharmacodynamics (effect of drugs on the body) and pharmacokinetics (ADME: absorption, distribution, metabolism and elimination) of drugs; an introduction to the process of new drug discovery and synthesis will also be taught. Prerequisite: CHEM 441 recommended.

CHEM 541. Biochemistry Lecture. 3 Credits.
This course is a one-semester survey of the major molecular constituents, bioenergetics, enzymes, nucleic acid structure, and genetic information transfer pathways fundamental to biochemistry.

CHEM 542. Biochemistry Laboratory. 4 Credits.
Principles and techniques of biochemical and immunological procedures involving protein characterization and isolation, enzymology, bioinformatics, and common molecular biology techniques for nucleic acids will be presented. (This is a writing intensive course.) Pre- or corequisite: CHEM 541 with a grade of C or better.

CHEM 543. Intermediate Biochemistry. 3 Credits.
This course presents and in-depth study of protein structure, folding, and synthesis. The major metabolic pathways will be studied in detail regarding thermodynamics and mechanism of regulation or control of individual enzymes and entire metabolic pathways. Concepts of metabolic disease will be introduced and effects on integrated metabolism will be presented. Prerequisite: CHEM 541 with a grade of C or better or equivalent.
CHEM 549. Environmental Chemistry. 3 Credits.
An overview of the natural chemical systems operating in the atmosphere, in the terrestrial environment (both water and soils), and in the oceans, and the potential effects that human activities may have on them. Specific topics include the origin and evolution of the earth and life, the chemistry of the atmosphere (including the ozone layer and greenhouse effect), the organic and inorganic components of soil and water, chemical weathering of rocks, metal complexation, biological processes in soil and water, and global-scale chemical processes.

CHEM 551. Advanced Inorganic Chemistry. 3 Credits.
Theoretical aspects of modern inorganic chemistry; bonding theories, stereochemistry, acid-base theories, coordination compounds, organometallic and bioinorganic compounds.

CHEM 552. Advanced Inorganic Chemistry Laboratory. 2 Credits.
Advanced topics in inorganic synthesis. Prerequisite: CHEM 551 with a grade of C or better.

CHEM 553. Essentials of Toxicology. 3 Credits.
Fundamental principles of toxicology: dose-response relationship, toxicologic testing, chemical and biological factors influencing toxicity, organ toxicology, carcinogenesis, mutagenesis, teratogenesis.

CHEM 560. Frontiers in Nanoscience and Nanotechnology. 1 Credit.
Nanotechnology presents unparalleled opportunities for advances in technology and medicine. Simultaneously, nanotechnology presents new challenges to organisms and to our environment. These undefined risk factors threaten to slow the development of new technologies and novel medical therapies. This course will review: structure, synthesis and properties of key nanomaterials; key applications of nanomaterials in technology and medicine; and impacts of nanomaterials on plant and animal physiology and the environment more generally. This course will be team-taught by faculty members in Biological Sciences, Chemistry and Biochemistry, and Engineering.

CHEM 669. In-Service Practicum. 3-6 Credits.
6 credits; 50 hours per credit. Prerequisites: CHEM 631 632. One semester of work experience in local hospital, forensic, or industrial laboratory. Available for pass/fail grading only.

CHEM 670. Graduate Orientation. 3 Credits.
An introduction to graduate studies in chemistry. Topics include responsible conduct of research (RCR), grant writing skills, oral presentation of chemical research and methods for searching the chemical literature. Attendance at departmental seminars is required. Limited to first-year chemistry doctoral students.

CHEM 685. Frontiers in Chemistry. 1-3 Credits.
Topics representing the most recent advances in various fields of chemistry or ones which represent an interdisciplinary advancement. Prerequisite: permission of the department chair.

CHEM 695. Topics in Chemistry. 1-3 Credits.
Study of selected topics in chemistry. Prerequisite: permission of the department chair.

CHEM 698. Master’s Research. 1-9 Credits.

CHEM 699. Master’s Thesis. 3 Credits.
Prerequisites: Departmental permission required.

CHEM 701. Advanced Analytical Chemistry. 3 Credits.
The theoretical and practical foundation of analysis with emphasis on recent analytical developments and current literature; topics may include figures of merit and data treatment, sampling and extraction, HPLC, electrochemistry, circular dichroism, FT-IR, Raman, MS, electrophoresis and NMR. Lectures are given by experts in those techniques.

CHEM 702. Advanced Analytical Chemistry II. 3 Credits.
This course will review the most cutting-edge advanced analytical chemistry instrumentation and methods, spanning three core areas of analytical chemistry (spectroscopy, separation, and electrochemistry) and offering an in-depth understanding of objectives, motivations, and future directions. The course will focus on advanced instrumentation and methodologies that can achieve ultra-sensitive analysis and detection, including single molecular spectroscopy, nanoparticle probes, high-speed separation in microfluidic devices, and ultramicroelectrodes for sensing and imaging. Prerequisites: Instrumental Analysis (or its equivalent).

CHEM 703. Chromatographic Separations by HPLC and GC. 3 Credits.
This course covers basic principles of chromatography emphasizing high performance liquid chromatography (HPLC) and gas chromatography (GC), as well as separation modes, instrumentation, detection methods, quantification, and sample preparation including solid phase extraction. Examples from environmental sciences, biosciences and industry will be stressed.

CHEM 704. HPLC and GC Laboratory. 2,3 Credits.
This lab course consists of six to seven independent HPLC and GC exercises based on examples from environmental, bioscience, and industrial applications.

CHEM 715. Automation and Management of the Clinical Chemistry Laboratory. 1 Credit.
The basic principles of management of the clinical chemistry laboratory and regulatory issues in laboratory management are presented. Prerequisite: CHEM 631 or permission of the instructor.

CHEM 716. Electrochemical Methods of Analysis. 1,2 Credit.
This course presents the fundamental principals and practical applications of modern electrochemical methods of analysis. Lectures and text readings cover the basic concepts and fundamental principals of this division of analytical techniques. Detailed descriptions and demonstrations of modern electrochemical research instrumentation will be provided. Students will obtain hands-on experience with this instrumentation by performing a required chemical determination using an electroanalytical method, and by undertaking a special analytical project. Research applications of other electroanalytical techniques and instrumentation, in addition to those actually used by the students in this course, will be discussed and/or demonstrated.

CHEM 720. Experimental Design and Data Treatment. 3 Credits.
A hands-on approach to experimental design and multivariate data analysis. Modern computer-based chemometric theories will be presented.

CHEM 722. Bonding and Group Theory. 3 Credits.
3 credits. Introduction to group theory and application to problems in bonding and spectroscopy.

CHEM 723. Modern Synthetic Organic Chemistry. 3 Credits.
An examination of the design of complex organic molecules. Topics covered will include retrosynthetic analysis, stereochemical control, and contemporary methods. Prerequisites: CHEM 415 or CHEM 515 or a pass in the organic placement exam.

CHEM 724. Bioinorganic Chemistry. 3 Credits.
This course is a survey of the mechanisms of biochemical activity of the trace elements. Topics include oxygen uptake, oxidation-reduction, metabolism, and toxicity.

CHEM 725. Physical Organic Chemistry. 3 Credits.
Approaches to the study of reaction mechanisms, including molecular orbital theory, thermochemistry, kinetics, isotop effects, solvent and substituent effects (including linear free energy relationships), acidity, acid catalysis, and detection of reactive intermediates.

CHEM 726. Medicinal Chemistry. 3 Credits.
Study of the chemistry and mode of action of various medicinal and physiologically active compounds. Prerequisites: CHEM 211 and CHEM 213 or one-year equivalent organic chemistry courses; CHEM 415/ CHEM 515 and CHEM 441/CHEM 541 are helpful.
CHEM 734. Organic Spectroscopy. 3 Credits.
Organic functional group and structure analysis with ultraviolet, infrared, nuclear magnetic resonance, mass, and other spectroscopic techniques.

CHEM 736. Introduction to Organic Synthesis. 3 Credits.
Detailed coverage of fundamental organic transformations with emphasis on reduction, oxidation, carbon-carbon bond formation, and protecting group strategy.

CHEM 740. Coordination and Transition Metal Chemistry. 3 Credits.
This course is based on the coordination and transition metal chemistry of first row, second row, and third row transition metals. Prerequisites: CHEM 351.

CHEM 742. Advanced Mass Spectrometry. 3 Credits.
This course trains students in the theory and application of advanced mass spectrometric methods as used in all subdisciplines of chemistry and biochemistry.

CHEM 743. Organic Geochemistry. 3 Credits.
Organic geochemistry is the study of organic compounds originally produced by photosynthesis and altered as they cycle through the soils, atmosphere, rivers, oceans, and crustal rocks. This course will include the carbon/oxygen cycles, biomarkers, organic matter diagenesis/catagenesis, analytical techniques used in organic geochemistry, and an introduction to carbon isotopes.

CHEM 744. NMR Spectroscopy. 3 Credits.
This course presents the basics of NMR spectroscopy. Topics include basic NMR theory, NMR instrumentation, one- and two-dimensional 1H and 13C techniques, and introduction to solid-state NMR.

CHEM 747. Medical Biochemistry. 3 Credits.
This course focuses on the applied biochemistry associated with human biological systems. Topics to be covered include the hormonal control of metabolism, vitamins, minerals, diagnostic tests; the biochemistry of the digestive system; connective tissue and bone; the immune system; the endocrine system; and the nervous systems, among others. Exams involve answering United States Medical Licensing Exam type questions in some instances. Medical biochemistry case studies are presented and discussed in class that relate to the biochemical basis of disease to enhance the learning experience. Students will also write a research paper and give an in-class presentation on selected topics. Prerequisites: CHEM 541 and CHEM 543 (or) CHEM 765.

CHEM 748. Environmental Chemistry Laboratory. 3 Credits.
Study of the basic principles and methods of trace chemical analysis of environmental systems, including spectroscopic, chromatographic, and electrochemical instrumental methods, in addition to wet chemical methods.

CHEM 749. Environmental Chemistry. 3 Credits.
An overview of the natural chemistry systems operating in the atmosphere, in the terrestrial environment (both water and soils), and in the oceans, and the potential effects that human activities may have on them. Specific topics include the origin and evolution of the earth and life, the chemistry of the atmosphere (including the ozone layer and greenhouse effect), the organic and inorganic components of soil and water, chemical weathering of rocks, metal complexation, biological processes in soil and water, and global-scale chemical processes.

CHEM 754. Quantum Chemistry. 3 Credits.
Overview of the development and application of quantum mechanics from a chemical perspective.

CHEM 755. Computational Chemistry. 3 Credits.
Comprehensive overview of ab initio (quantum) calculations and molecular dynamic simulations, the two most widely used computational methods. Plus a brief overview of other computational applications in chemistry and biology. Prerequisites: CHEM 754 or permission of the instructor.

CHEM 756. Inorganic Reaction Mechanisms. 3 Credits.
This course is a survey of the major mechanisms of inorganic and organometallic chemistry. Topics include kinetics, ligand substitution, electron transfer, and photochemistry.

CHEM 757. Organic Chemistry Mechanisms. 3 Credits.
The application of physical organic techniques to study the mechanisms of key organic reactions and the structures of reaction intermediates. Includes photochemistry and pericyclic reactions. Prerequisites: CHEM 725 and CHEM 825.

CHEM 758. Atmospheric Chemistry. 3 Credits.
An introductory survey of atmospheric chemistry and physics. Topics to be covered include atmospheric composition, atmospheric pressure, simple models, atmospheric transport, geochemical cycles, the greenhouse effect, aerosols, stratospheric ozone, the oxidizing power of the troposphere, ozone air pollution, satellite orbits, and radiative transfer. The course will also provide a survey of satellite remote sensing. It will conclude with the basics of satellite remote sensing, including a brief survey of satellite instruments.

CHEM 760. Molecular Spectroscopy. 3 Credits.
An introductory survey of the rotational, vibrational and electronic spectroscopy of molecules from the perspective of quantum mechanics and group theory. Prerequisite: CHEM 333.

CHEM 762. Advanced Techniques in Biochemistry. 1-3 Credits.
A laboratory course in modern experimental methodology and instrumentation in biochemistry.

CHEM 765. Advanced Biochemistry. 3 Credits.
This course will cover macromolecular structure, function, thermodynamic stability and folding kinetics; protein chemistry; molecular biology; and molecular mechanisms of disease and bioinformatics.

CHEM 769. Nucleic Acids Biochemistry. 3 Credits.
A comprehensive presentation of the chemistry of RNA and DNA, including modern concepts of gene regulation, the control over transcription, RNA processing and translation, cell cycle control and molecular carcinogenesis.

CHEM 775. Physical Biochemistry. 3 Credits.
This course will examine the physical characterization of macromolecules, polarized light, absorption and fluorescence, sedimentation and transport hydrodynamics, electrophoretic mobility, light scattering, and structural X-ray crystallography of proteins and nucleic acids.

CHEM 779. Kinetics and Thermodynamics. 3 Credits.
A survey of modern theories of reaction rates and mechanisms, classic thermodynamic functions, and an introduction to statistical thermodynamics.

CHEM 790. Master's Seminar. 1 Credit.
Master's students attend seminars given by researchers from across the country in order to expose them to additional areas of research in chemistry and biochemistry.

CHEM 791. Master's Seminar. 2 Credits.
Master's students attend seminars, attend a class on giving seminars, and present a seminar on their own research.

CHEM 795. Selected Topics in Chemistry and Biochemistry. 3 Credits.
Thorough coverage of areas selected to meet special needs and interests. Prerequisite: permission of the instructor.

CHEM 801. Advanced Analytical Chemistry. 3 Credits.
The theoretical and practical foundation of analysis with emphasis on recent analytical developments and current literature; topics may include figures of merit and data treatment, sampling and extraction, HPLC, electrochemistry, circular dichroism, FT-IR, Raman, MS, electrophoresis and NMR. Lectures are given by experts in those techniques.

CHEM 802. Advanced Analytical Chemistry II. 3 Credits.
This course will review the most cutting-edge advanced analytical chemistry instrumentation and methods, spanning three core areas of analytical chemistry (spectroscopy, separation, and electrochemistry) and offering an in-depth understanding of objectives, motivations, and future directions. The course will focus on advanced instrumentation and methodologies that can achieve ultra-sensitive analysis and detection, including single molecular spectroscopy, nanoparticle probes, high-speed separation in microfluidic devices, and ultrasensitive electrodes for sensing and imaging.
CHEM 813. Biomedical Sciences Laboratory. 3 Credits.
This course is designed to enable graduate students to learn a broad range of basic and modern biochemical and biomedical techniques, methods, and state-of-the-art instrumentation, to train students how to apply these techniques and knowledge to their future research, and to gain the essential training and skills to conduct original and independent research projects. It includes: (i) conducting an effective literature search; (ii) selecting a research topic; (iii) formulating new ideas and hypotheses; (iv) designing new experiments to test the hypotheses and ideas; (v) carrying out experiments; and (vi) recording, interpreting and presenting findings. Prerequisites: approval of the program director.

CHEM 814. Biomedical Sciences Laboratory. 3 Credits.
This course is designed to enable graduate students to learn a broad range of basic and modern biochemical and biomedical techniques, methods, and state-of-the-art instrumentation, to train students how to apply these techniques and knowledge to their future research, and to gain the essential training and skills to conduct original and independent research projects. It includes: (i) conducting an effective literature search; (ii) selecting a research topic; (iii) formulating new ideas and hypotheses; (iv) designing new experiments to test the hypotheses and ideas; (v) carrying out experiments; and (vi) recording, interpreting and presenting findings. Prerequisites: approval of the program director.

CHEM 815. Biomedical Sciences Laboratory. 3 Credits.
This course is designed to enable graduate students to learn a broad range of basic and modern biochemical and biomedical techniques, methods, and state-of-the-art instrumentation, to train students how to apply these techniques and knowledge to their future research, and to gain the essential training and skills to conduct original and independent research projects. It includes: (i) conducting an effective literature search; (ii) selecting a research topic; (iii) formulating new ideas and hypotheses; (iv) designing new experiments to test the hypotheses and ideas; (v) carrying out experiments; and (vi) recording, interpreting and presenting findings. Prerequisites: approval of the program director.

CHEM 816. Electrochemical Methods of Analysis. 1,2 Credit.
This course presents the fundamental principals and practical applications of modern electrochemical methods of analysis. Lectures and text readings cover the basic concepts and fundamental principals of this division of analytical techniques. Detailed descriptions and demonstrations of modern electrochemical research instrumentation will be provided. Students will obtain hands-on experience with this instrumentation by performing a required chemical determination using an electroanalytical method, and by undertaking a special analytical project. Research applications of other electroanalytical techniques and instrumentation, in addition to those actually used by the students in this course, will be discussed and/or demonstrated.

CHEM 822. Bonding and Group Theory. 3 Credits.
Introduction to group theory and application to problems in bonding and spectroscopy.

CHEM 823. Modern Synthetic Organic Chemistry. 3 Credits.
An examination of the design of complex organic molecules. Topics covered will include retrosynthetic analysis, stereoechemical control, and contemporary methods.

CHEM 824. Bioinorganic Chemistry. 3 Credits.
This course is a survey of the mechanisms of biochemical activity of the trace elements. Topics include oxygen uptake, oxidation-reduction, metabolism, and toxicity.

CHEM 825. Physical Organic Chemistry. 3 Credits.
Approaches to the study of reaction mechanisms, including molecular orbital theory, thermochemistry, kinetics, isotop effects, solvent and substituent effects (including linear free energy relationships), acidity, acid catalysis, and detection of reactive intermediates.

CHEM 826. Medicinal Chemistry. 3 Credits.
Study of the chemistry and mode of action of various medicinal and physiologically active compounds.

CHEM 834. Organic Spectroscopy. 3 Credits.
Organic functional group and structure analysis with ultraviolet, infrared, nuclear magnetic resonance, mass, and other spectroscopic techniques.

CHEM 836. Introduction to Organic Synthesis. 3 Credits.
Detailed coverage of fundamental organic transformations with emphasis on reduction, oxidation, carbon-carbon bond formation, and protecting group strategy.

CHEM 840. Coordination and Transition Metal Chemistry. 3 Credits.
This course examines the coordination and transition metal chemistry of first row, second row, and third row transition metals.

CHEM 842. Advanced Mass Spectrometry. 3 Credits.
This course trains students in the theory and application of advanced mass spectrometric methods as used in all subdisciplines of chemistry and biochemistry.

CHEM 843. Organic Geochemistry. 3 Credits.
Organic geochemistry is the study of organic compounds originally produced by photosynthesis and altered as they cycle through the soils, atmosphere, rivers, oceans, and crustal rocks. This course will include the carbon/oxygen cycles, biomarkers, organic matter diagenesis/catagenesis, analytical techniques used in organic geochemistry, and an introduction to carbon isotopes.

CHEM 844. NMR Spectroscopy. 3 Credits.
This course presents the basics of NMR spectroscopy. Topics include basic NMR theory, NMR instrumentation, one- and two-dimensional 1H and 13C techniques, and introduction to solid-state NMR.

CHEM 847. Medical Biochemistry. 3 Credits.
This course focuses on the applied biochemistry associated with human biological systems. Topics to be covered include the hormonal control of metabolism, vitamins, minerals, diagnostic tests; the biochemistry of the digestive system; connective tissue and bone; the immune system; the urinary system; and the nervous systems, among others. Exams involve answering United States Medical Licensing Exam type questions in some instances. Medical biochemistry case studies are presented and discussed in class that relate to the biochemical basis of disease to enhance the learning experience. Students will also write a research paper and give an in-class presentation on selected topics.

CHEM 849. Environmental Chemistry. 3 Credits.
An overview of the natural chemistry systems operating in the atmosphere, in the terrestrial environment (both water and soils), and in the oceans, and the potential effects that human activities may have on them. Specific topics include the origin and evolution of the earth and life, the chemistry of the atmosphere (including the ozone layer and greenhouse effect), the organic and inorganic components of soil and water, chemical weathering of rocks, metal complexation, biological processes in soil and water, and global-scale chemical processes.

CHEM 854. Quantum Chemistry. 3 Credits.
Overview of the development and application of quantum mechanics from a chemical perspective.

CHEM 855. Computational Chemistry. 3 Credits.
Comprehensive overview of ab initio (quantum) calculations and molecular dynamic simulations, the two most widely used computational methods. Plus a brief overview of other computational applications in chemistry and biology.

CHEM 856. Inorganic Reaction Mechanisms. 3 Credits.
This course is a survey of the major mechanisms of inorganic and organometallic chemistry. Topics include kinetics, ligand substitution, electron transfer, and photochemistry.

CHEM 857. Organic Chemistry Mechanisms. 3 Credits.
The application of physical organic techniques to study the mechanisms of key organic reactions and the structures of reaction intermediates. Includes photochemistry and pericyclic reactions. Prerequisites: CHEM 725 and CHEM 825.
CHEM 858. Atmospheric Chemistry. 3 Credits.
An introductory survey of atmospheric chemistry and physics. Topics to be covered include atmospheric composition, atmospheric pressure, simple models, atmospheric transport, geochemical cycles, the greenhouse effect, aerosols, stratospheric ozone, the oxidizing power of the troposphere, ozone air pollution, satellite orbits, and radiative transfer. The course will also provide a survey of satellite remote sensing. It will conclude with the basics of satellite remote sensing, including a brief survey of satellite instruments.

CHEM 859. Statistical Thermodynamics in Chemistry. 3 Credits.
An introduction to statistical mechanics from a chemical perspective. Topics to be covered include ensembles and postulates and their mathematical background; basic thermodynamics; distinguishable and indistinguishable systems; ideal monatomic gas; monatomic crystals; ideal diatomic gas; ideal polyatomic gas; chemical equilibrium; rates of chemical reactions; and quantum statistics. Prerequisites: Permission from department chair.

CHEM 860. Molecular Spectroscopy. 3 Credits.
An introductory survey of the rotational, vibrational and electronic spectroscopy of molecules from the perspective of quantum mechanics and group theory.

CHEM 862. Advanced Techniques in Biochemistry. 1-3 Credits.
A laboratory course in modern experimental methodology and instrumentation in biochemistry.

CHEM 865. Advanced Biochemistry. 3 Credits.
This course will cover macromolecular structure, function, thermodynamic stability and folding kinetics; protein chemistry; molecular biology; and molecular mechanisms of disease and bioinformatics.

CHEM 868. Internship - Chemistry & Biochemistry. 1 Credit.
This course is designed to provide individual students with advanced on-the-job professional experience. Internship assignments must be approved within the student's program of study. Direct supervision is given by an experienced professional at the internship site.

CHEM 869. Nucleic Acids Biochemistry. 3 Credits.
A comprehensive presentation of the chemistry of RNA and DNA, including modern concepts of gene regulation, the control over transcription, RNA processing and translation, cell cycle control and molecular carcinogenesis.

CHEM 875. Physical Biochemistry. 3 Credits.
This course will examine the physical characterization of macromolecules, polarized light, absorption and fluorescence, sedimentation and transport hydrodynamics, electrophoretic mobility, light scattering, and structural x-ray crystallography of proteins and nucleic acids.

CHEM 879. Kinetics and Thermodynamics. 3 Credits.
A survey of modern theories of reaction rates and mechanisms, classic thermodynamic functions, and an introduction to statistical thermodynamics.

CHEM 890. Chemistry Seminar. 1 Credit.
Students attend seminars given by researchers from across the country on order to expose them to additional areas of research in chemistry and biochemistry.

CHEM 891. Doctoral Seminar. 2 Credits.
Students attend seminars; attend a class on giving seminars; and present a seminar on their own research.

CHEM 895. Intern in Clinical Laboratory Management. 1-3 Credits.
Lecture and discussion of recent advances in the field of biomedical sciences.

CHEM 898. Doctoral Research. 1-9 Credits.

CHEM 899. Doctoral Graduate Credit. 1 Credit.
This course is a pass/fail course doctoral students may take to maintain active status after successfully passing the candidacy examination. All doctoral students are required to be registered for at least one graduate credit hour every semester until their graduation.

CHEM 998. Master's Graduate Credit. 1 Credit.
This course is a pass/fail course master's students in their final semester. It may be taken to fulfill the registration requirement necessary for graduation. All master's students are required to be registered for at least one graduate credit hour in the semester of their graduation.