# Department of Chemistry

At KU Chemistry, our faculty are dedicated to mentoring both undergraduate and graduate students and to helping each student achieve scientific maturity. In addition to required classroom and laboratory courses, students can participate in research projects led by our faculty. Our Department's research programs (https://chem.ku.edu/research-areas/) place KU Chemistry at the leading edge of scientific research. The research performed by our faculty and students applies chemical knowledge to develop compounds that fight disease, create cleaner and more efficient chemical processes for industry, and apply chemistry in other manners that benefit society.

Our highly recognized faculty (https://chem.ku.edu/faculty/) excel at both teaching and research. KU Chemistry spans two buildings: Gray-Little Hall (https://gray-little.ku.edu/) on main campus and the Multidisciplinary Research Building (MRB) (https://adamsinstitute.ku.edu/multidisciplinary-research-building/) on west campus. Our graduate students (https://chem.ku.edu/graduate-students/) come from throughout the U.S. and across the globe to pursue their educational and research goals. Many other students pursue graduate degrees in related areas of medicinal chemistry, pharmaceutical chemistry, chemical engineering, biochemistry, and geochemistry, making a community of more than 350 chemistry-oriented research students. To aid the research efforts of our faculty and students, the Chemistry Department and University support a range of core research labs (https://research.ku.edu/ku-core-research-labs/) and facilities. These include a Nuclear Magnetic Resonance Laboratory (https://nmrlab.ku.edu/), X-ray Crystallography Laboratory (https://psxl.ku.edu/), Ralph N. Adams Nanofabrication Facility (https://nanofab.ku.edu/), and Advanced Computing Facility (https://technology.ku.edu/research/advanced-computing-facility/). KU Chemistry faculty and students are involved in multidisciplinary centers, such as the Adams Institute for Bioanalytical Chemistry (https://adamsinstitute.ku.edu/) and the Center for Environmentally Beneficial Catalysis (https://cebc.ku.edu/), which enable cutting edge research to solve urgent problems related to human health and the environment.

## Undergraduate Program

The undergraduate program in the Department of Chemistry has two primary missions: 1) to enable majors to master the discipline in preparation for further study or immediate employment; and 2) to empower majors in other disciplines to acquire a foundational knowledge of chemistry.

The curriculum leading to the **Bachelor of Science (B.S.)** degree, a rigorous program certified by the American Chemical Society, consists of a full spectrum of chemistry courses as well as supporting courses in mathematics, physics, and biochemistry. The B.S. degree is designed to prepare students for a professional career in chemistry. The **Bachelor of Arts (B.A.)** degree, with fewer required courses, allows students to obtain a broader knowledge of areas outside chemistry, or to tailor their chemistry program for specific or unique objectives. We also offer a **Minor** in chemistry for those seeking a secondary area of study.

## Graduate Program

For a student wishing to earn a **Doctor of Philosophy (Ph.D.)** degree or a **Master of Science (M.S.)** degree in chemistry, the selection of a graduate school is one of the most important career decisions. Graduate studies in Chemistry at KU aim to prepare students to become independent, creative chemists ready to tackle the challenges of the 21st century.

The KU Chemistry Graduate Program provides exceptional and diverse opportunities for students interested in a career in cutting-edge research, higher education, or any number of chemically related positions requiring an advanced degree. Our outstanding faculty provide mentoring and guidance to graduate students during their journey from undergraduate to professional.

## Undergraduate Programs

Chemistry course work educates undergraduates to become professional chemists or to do graduate work in chemistry. It also provides the basic chemistry background for students entering such fields as biochemistry, biological sciences, dentistry, engineering, environmental science, geology, medicine, pharmacy, physics, and secondary-level science education. Courses in chemistry provide general knowledge and appreciation of chemistry and its impact on society.

## Advanced Placement

Students who have taken the Advanced Placement Examination in chemistry should have the results forwarded to the Office of Admissions (http://admissions.ku.edu/). Students who score 4 or 5 need not take CHEM 130 and CHEM 135 and receive 10 hours of credit. Those who score 3 receive credit for CHEM 130. Students who score at least 50 on the College Level Examination Program general chemistry examination receive 5 hours of credit in CHEM 130.

## Courses for Non-majors

Undergraduates taking chemistry as preparatory study for another field should consult the courses listed for that field in this catalog. CHEM 110 is an introductory course for the non-science major who wants to study the general principles, methods, role, and significance of chemistry in the modern world, for pre-nursing students, and for students who plan to take no additional courses in chemistry. Pre-medical students and chemistry or other science majors should not take CHEM 110. CHEM 110 includes a laboratory. Engineering students who need only one semester of chemistry should take CHEM 150. CHEM 130 is an introductory course for students who plan to take more than one year of college chemistry, including chemical engineering, pre-medical, pre-pharmacy, and pre-dental students and students in biological sciences who must take organic chemistry. Students should continue with CHEM 135 in the same academic year that they take CHEM 130.

## Graduate Programs

The department's graduate program, its Ph.D. program in particular, produces graduates with the basic knowledge, skills, and experimental training necessary to enter productive careers in academic, industrial, and government positions. Faculty and graduate students work collegially, not only in the search for new knowledge at the frontiers of chemistry, but also toward the solution of problems of fundamental societal concern.

Although the department believes it is essential to provide graduate students with a knowledge base spanning the traditional areas of analytical, inorganic, organic, and physical chemistry, it nurtures its particular strengths in several important research areas at the interface of chemistry and the biological/medical sciences. The Department of Chemistry at KU is a worldwide leader in graduate training and research in bioanalytical chemistry, and its additional interactions with

the pharmaceutical and biological sciences have led to strong graduate research programs in diverse areas such as bio-inorganic, bio-organic, and biophysical chemistry.

The department also recognizes its central science role by maintaining strong research and Ph.D. programs in areas that interface closely with molecular biosciences, physics, chemical engineering, mathematics, and computer science, for example, in drug discovery, theoretical chemistry, materials, molecular modeling, and laser spectroscopy. The entering Ph.D. student can be assured of finding vigorous programs spanning a full range of chemical studies, and the graduating Ph.D. student can be equally confident that his or her training and skills are marketable commodities.

The department's M.S. program is a traditional companion to the Ph.D. program and shares the same goals. It is encouraged for students who prefer a program with less depth and a research (thesis) project that is manageable in 2 to 4 semesters. Although most entering graduate students choose the Ph.D.—the most desirable degree for those who wish to work as independent scientists in academic, industrial, or institutional settings—the M.S. serves a useful and essential role for students with other ambitions.

Research support facilities include the Instrumentation Design Laboratory, Mass Spectrometry Laboratory, Molecular Graphics and Modeling Laboratory, Nuclear Magnetic Resonance Laboratory, and X-ray Crystallography Laboratory. Anschutz Library contains more than 300,000 books and periodicals spanning the fields of chemistry, biochemistry, physics, geology, and pharmacy.

## Non-Degree Seeking

Students who are interested in enrolling in graduate level coursework in the Department of Chemistry without formal admission to a graduate program at KU are encouraged to apply for graduate non-degree seeking student status. See the department's degrees (https://chem.ku.edu/degrees/) webpage for further details.

## Courses

**CHEM 110. Introductory Chemistry. 5 Credits. LFE**
This integrated lecture and laboratory course provides an introduction to basic concepts related to general, organic, and biological chemistry. Suitable for students seeking an introductory course and for students who are majoring in health and allied health fields. Students whose majors require more than one semester of chemistry should enroll in CHEM 130, CHEM 170, or CHEM 190. CHEM 110 and CHEM 150 cannot both be taken for credit.

**CHEM 130. General Chemistry I. 5 Credits. LFE**
This course seeks to develop a working knowledge of the conceptual foundation and the quantitative chemical relationships on which subsequent chemistry courses are built. Atomic structure, chemical bonding, reaction stoichiometry, thermochemistry, and periodic trends are emphasized in this integrated lecture and laboratory course. Students pursuing or considering a major in one of the chemical sciences should strongly consider taking CHEM 170 or CHEM 190. Students with credit in CHEM 110 will have two hours added on to their total number of hours required for graduation. Prerequisite: Must be eligible for MATH 115.

**CHEM 135. General Chemistry II. 5 Credits. LFE**
This course, which is a continuation of CHEM 130, focuses on chemical kinetics, chemical equilibrium, acid-base chemistry, and thermodynamics. Additional topics, such as environmental chemistry, electrochemistry, coordination chemistry, nuclear chemistry, organic chemistry, and/or polymers, may also be introduced in this integrated lecture and laboratory course. Students pursuing or considering a major in one of the chemical sciences should strongly consider taking CHEM 175 or CHEM 195. Prerequisite: CHEM 130, CHEM 170, or CHEM 190 with a grade of C- or higher.

**CHEM 149. Chemistry for Engineers Supplement. 2 Credits.**
This course is intended for students in the School of Engineering who have credit for CHEM 130 but still need selected elements of second-semester general chemistry. Students will learn to describe phases of matter and quantify changes among them, and to analyze chemical equations and equilibria in the context of acid-base and redox chemistry. Prerequisite: Student in the School of Engineering and CHEM 130 or equivalent (or have Departmental consent). Credit in CHEM 135, CHEM 150, CHEM 175, or CHEM 195 precludes enrollment in and credit for CHEM 149.

**CHEM 150. Chemistry for Engineers. 5 Credits. LFE**
This one semester course is designed for students in the School of Engineering who are not required to take additional chemistry courses at the college level. In this integrated lecture and laboratory course, students will learn to predict properties of substances based on their molecular structure, to describe phases of matter and quantify changes among them, and to analyze chemical equations and equilibria in the context of acid-base and redox chemistry. Technical communication and experimental design are also emphasized. Prerequisite: Must have completed a course in high school chemistry and be eligible for MATH 115 (or have Departmental consent). Students not admitted to the School of Engineering must receive permission from instructor. CHEM 110 and CHEM 150 cannot both be taken for credit.

**CHEM 170. Chemistry for the Chemical Sciences I. 5 Credits. LFE**

The first course in a two-course sequence focused on the principles and applications of modern chemistry. This integrated lecture and laboratory course is designed for students pursuing or considering a major in one of the chemical sciences (such as chemistry, biochemistry, chemical engineering or petroleum engineering). The CHEM 170/CHEM 175 course sequence covers the same general topics as CHEM 130/CHEM 135, but with an increased emphasis on modern applications of chemistry. Students with credit in CHEM 110 will have two hours added on to their total number of hours required for graduation. Prerequisite: Eligibility for MATH 115.

**CHEM 175. Chemistry for the Chemical Sciences II. 5 Credits. LFE**

An integrated lecture and laboratory course which is a continuation of CHEM 170. Prerequisite: CHEM 130, CHEM 170, or CHEM 190 with a grade of C- or higher.

**CHEM 180. Seminar I. 0.5 Credits.**
Special topics for chemistry majors such as using the chemical literature, educational and professional perspectives, scientific ethics, and undergraduate research opportunities. It is recommended that students take this half-semester course in their freshman or sophomore year. Prerequisite: A declared major in chemistry or consent of instructor.

**CHEM 190. Foundations of Chemistry I, Honors. 3 Credits. LFE**
CHEM 190, together with corequisite laboratory course CHEM 191, provides an integrated treatment of theoretical and experimental aspects of chemistry for qualified and highly motivated students. It is anticipated that students in CHEM 190 and CHEM 191 plan to take more than one year of chemistry at the college level. Students with credit in CHEM 110 will have two hours added on to their total number of hours required for graduation. Prerequisite: High school chemistry and calculus; at least one of the following: (a) acceptance into the KU Honors Program, (b) an AP

exam score in chemistry of 3 or higher, (c) a mathematics ACT score of 30 or higher; or permission of instructor. Corequisite: CHEM 191.

**CHEM 191. Foundations of Chemistry I Laboratory, Honors. 2 Credits. LFE**
Laboratory course for students enrolled in CHEM 190. Prerequisite: Corequisite: CHEM 190.

**CHEM 195. Foundations of Chemistry II, Honors. 3 Credits. LFE**
CHEM 195 and corequisite laboratory course CHEM 196 continue the integrated theoretical and experimental exploration of chemistry topics for qualified and highly motivated students. Prerequisite: CHEM 130, CHEM 170, or CHEM 190 and CHEM 191 with a grade of C- or better, and permission of the instructor. Corequisite: CHEM 196.

**CHEM 196. Foundations of Chemistry II Laboratory, Honors. 2 Credits. LFE**
Laboratory course for students enrolled in CHEM 195. Prerequisite: CHEM 130, CHEM 170, or CHEM 190 and CHEM 191 with a grade of C- or better, and permission of the instructor. Corequisite: CHEM 195.

**CHEM 201. Laboratory Safety in the Chemical Sciences. 1 Credits.**

A course for undergraduate students focusing on chemical safety in modern laboratories. The course will feature practical instruction in lab safety, an introduction to safety resources, and group discussions centered around case studies. Required for all B.S. majors, and for all B.A. majors participating in undergraduate research. Students with credit in CHEM 201 may not take CHEM 701 for credit. Prerequisite: CHEM 135, CHEM 175, or CHEM 195.

**CHEM 250. Mathematical Methods for the Chemical Sciences. 3 Credits.**
A one-semester course covering advanced mathematical methods necessary for upper-level physical and analytical chemistry courses. Topics include complex numbers and functions, ordinary and partial differential equations, linear algebra and probability and statistics with special emphasis on applications to problems in the chemical sciences. Prerequisite: Corequisite: MATH 127.

**CHEM 330. Organic Chemistry I. 3 Credits.**
A study of the structure and reactivity of selected classes of organic compounds. CHEM 330 is the first course of a two-semester sequence. Prerequisite: CHEM 135, CHEM 175, or CHEM 195 with a grade of C- or higher.

**CHEM 331. Organic Chemistry I Laboratory. 2 Credits. LFE**
Emphasis on basic techniques for the preparation, separation, and purification of organic compounds. Required for a major in chemistry and by those departments and programs specifying a complete undergraduate organic chemistry course. Prerequisite: CHEM 330 or CHEM 380 with a grade or C- or higher or concurrent enrollment in CHEM 330 or CHEM 380.

**CHEM 335. Organic Chemistry II. 3 Credits.**
A continuation of CHEM 330, intended for students who want further training in organic chemistry. Prerequisite: CHEM 330 or CHEM 380 with a grade of C- or higher.

**CHEM 336. Organic Chemistry II Laboratory. 2 Credits. LFE**
More advanced organic laboratory techniques with emphasis on modern spectroscopic methods for determining the structure and purity of organic compounds. Prerequisite: CHEM 331 and CHEM 335 or CHEM 385 with a grade or C- or higher or concurrent enrollment in CHEM 335 or CHEM 385.

**CHEM 380. Organic Chemistry I, Honors. 3 Credits.**
This is the first half of a two-semester sequence in organic chemistry for students with strong records in previous chemistry courses. Recommended for members of the University Honors Program and students majoring in chemistry or related fields. Prerequisite: CHEM 135, CHEM 175, or CHEM 195 with a grade of C- or higher and permission of the instructor.

**CHEM 385. Organic Chemistry II, Honors. 3 Credits.**
This is the second course in a two-semester sequence in organic chemistry for students with strong records in previous chemistry courses. Recommended for members of the University Honors Program and students majoring in chemistry or related fields. Prerequisite: CHEM 330 or CHEM 380 with a grade of C- or higher, and permission of the instructor.

**CHEM 390. Topics in Chemistry, Honors: _____. 1-5 Credits.**
A course on special topics in chemistry, given as the need arises. Course content applies and expands upon general chemistry concepts, such as chemical thermodynamics, kinetics, and bonding. In this course, students gain knowledge in a topic of contemporary interest in chemistry, are challenged to examine the experimental and theoretical basis of this knowledge, and consider the broader impacts of this knowledge outside the discipline. Course may be repeated for different topics. Prerequisite: CHEM 135, CHEM 175 or CHEM 195 and membership in the University Honors Program; or permission of instructor. Each section may have additional prerequisites to be determined by the instructor.

**CHEM 400. Analytical Chemistry. 3 Credits.**
Principles of analytical chemistry with emphasis on the fundamental methods used for chemical analysis. Topics include experimental error, statistical analysis, method development, sampling, calibration methods, spectrophotometry, chromatography, mass spectrometry, and electrochemistry. Prerequisite: One semester of organic chemistry and one semester of organic chemistry laboratory, or permission of instructor. Corequisite: CHEM 401.

**CHEM 401. Analytical Chemistry Laboratory. 2 Credits.**
Experiments illustrate fundamental principles of chemical analysis methods. The course serves as an introduction to advanced instrumental methods of analysis. Prerequisite: One semester of organic chemistry and one semester of organic chemistry lab, or permission of instructor. Corequisite: CHEM 400.

**CHEM 450. Directed Readings/Laboratory in Chemistry. 1-3 Credits.**
Individual and supervised study or laboratory work on special topics or problems in chemistry. Prerequisite: Ten hours of chemistry and a minimum overall grade-point average of 2.0 or consent of department.

**CHEM 498. Undergraduate Research. 1-2 Credits.**
A research course for Chemistry majors, consisting of experimental or theoretical work in chemistry or a closely related field. A final report must be submitted to the instructor at the end of the semester. This course may be taken up to 7 times for a maximum of 7 credit hours. Prerequisite: CHEM 201, or CHEM 201 concurrently, or documentation of appropriate laboratory safety training.

**CHEM 510. Biological Physical Chemistry. 3 Credits.**
A one-semester course that explores the fundamentals of physical chemistry with specific application to biological systems. The basic principles of thermodynamics, chemical kinetics, quantum mechanics and spectroscopy will be introduced, and their application to aqueous solutions and biochemical systems will be emphasized. This class consists of lecture only. Students requiring laboratory experience should enroll in CHEM 520. Prerequisite: One semester of organic chemistry, two semesters of calculus, and two semesters of physics.

**CHEM 520. Biological Physical Chemistry with Laboratory. 5 Credits.**
A one-semester integrated lecture and laboratory course that explores the fundamentals of physical chemistry with specific application to biological systems. The basic principles of thermodynamics, chemical kinetics, quantum mechanics and spectroscopy will be introduced, and their applications to aqueous solutions and biochemical systems will be emphasized. Students who do not wish to take the laboratory component should enroll in CHEM 510. Prerequisite: One semester of organic chemistry, two semesters of calculus and two semesters of physics.

**CHEM 525. Physical Chemistry for Engineers. 4 Credits.**
An introduction to the basic principles of quantum mechanics, atomic and molecular structure, molecular rotations and vibrations, statistical mechanics, statistical thermodynamics and reaction dynamics. Prerequisite: Two semesters of general chemistry; PHSX 212; MATH 127, MATH 220 or MATH 320 and MATH 290 or consent of instructor.

**CHEM 530. Physical Chemistry I. 4 Credits.**
An introduction to the basic principles of quantum mechanics, atomic and molecular structure, molecular rotations and vibrations, group theory, spectroscopy, and statistical mechanics. Prerequisite: Two semesters of general chemistry; PHSX 212; MATH 127; and CHEM 250 (or MATH 220 or MATH 320 and completion of, or concurrent enrollment in MATH 290) or consent of instructor.

**CHEM 535. Physical Chemistry II. 3 Credits.**
Emphasizes the thermodynamics of molecular systems with application to the structure and properties of gases, liquids, solids, materials, statistical thermodynamics, chemical kinetics, and reaction dynamics. Prerequisite: CHEM 530 or consent of instructor.

**CHEM 537. Physical Chemistry Laboratory. 3 Credits. LFE**
Experiments in physical chemistry, with emphasis on the fundamental principles of quantum mechanics, spectroscopy, thermodynamics and kinetics as applied to chemical systems. Prerequisite: CHEM 401 and CHEM 530 and concurrent enrollment in CHEM 535.

**CHEM 560. Introduction to Chemical Biology. 3 Credits.**
A course for students with an interest in the application of chemical principals and methods to address problems in biology at the molecular level. The fundamentals of biomolecules (nucleic acids, proteins, lipids, and carbohydrates) and techniques of chemical biology research will be discussed. This course is offered at the 500 and 700 level with additional assignments at the 700 level. Not open to students with credit in CHEM 760. Prerequisite: CHEM 335 and CHEM 336 with grades of C- or higher and completion of, or concurrent enrollment in BIOL 600 or BIOL 636, or consent of instructor.

**CHEM 598. Research Methods. 3 Credits. LFE**
An introduction for pre-service teachers to the tools used by scientists to solve scientific problems. Topics include design of experiments and interpretation of their results, use of statistics, mathematical modeling, laboratory safety, ethical treatment of human subjects, writing scientific papers, giving oral presentations, and obtaining data from the scientific literature. Open only to students in the UKanTeach program. (Same as PHSX 598.) Prerequisite: At least one course at the 100 level or above in CHEM, MATH, or PHSX.

**CHEM 635. Instrumental Methods of Analysis. 2 Credits.**
Theory and application of instrumental methods to modern analytical problems. Topics covered include atomic and molecular spectroscopy, electrochemistry, mass spectrometry, and separations. Prerequisite: CHEM 400 and CHEM 401 and one semester of physical chemistry laboratory, or permission of instructor.

**CHEM 636. Instrumental Methods of Analysis Laboratory. 3 Credits. LFE**
Theory and application of instrumental methods to modern analysis problems. Experiments covered in this laboratory course, which satisfies the Capstone requirement, include atomic and molecular spectroscopy, electrochemistry, and separation methods. Prerequisite: CHEM 400 and CHEM 401, and one semester of physical chemistry laboratory; or permission of instructor. Prerequisite or Corequisite: CHEM 635.

**CHEM 660. Inorganic Chemistry. 3 Credits.**
Introduction#to the principles of structure, bonding, and reactivity of inorganic and organometallic species, with particular emphasis on symmetry,#bonding models, ligand classifications, spectroscopy,#and chemical transformations of commonly encountered classes of metal-containing compounds. Prerequisite: CHEM 510, CHEM 520, or CHEM 530.

**CHEM 661. Advanced Inorganic Laboratory. 2 Credits. LFE**
Experiments concerning the synthesis and characterization of inorganic compounds. Prerequisite: CHEM 660 or concurrent enrollment in CHEM 660.

**CHEM 680. Topics in Chemistry: _____. 1-5 Credits.**
Courses on special topics in chemistry, given as the need arises. Course may be repeated for different topics. Prerequisite: 20 hours of Chemistry. Each section may have additional prerequisites to be determined by the instructor.

**CHEM 695. Seminar II. 0.5 Credits.**
Special topics and presentations by students and faculty in areas of current interest such as recent advancements in chemistry, professional development, societal issues facing chemists, and reports of ongoing research. This half-semester course is recommended for seniors. Prerequisite: CHEM 180.

**CHEM 698. Undergraduate Capstone Research. 1-2 Credits.**
An undergraduate capstone research experience in chemistry or a closely related field, consisting of experimental or theoretical work on a topic developed in consultation with the faculty research advisor. A total of 3 credit hours must be accumulated for the course to count toward the Capstone requirement. This course may be taken up to 3 times for a maximum of 3 credit hours. Students will submit interim reports during the semesters in which the first and second credit hours are completed, and a final report to the Chemistry Department during the semester in which the third credit hour is completed, and also present their results in a public forum. Prerequisite: CHEM 201, or CHEM 201 concurrently (or documentation of appropriate laboratory safety training), CHEM 335 (or CHEM 385) and CHEM 336 with grades of C or higher, and permission of the Chemistry Department.

**CHEM 699. Undergraduate Honors Research. 1-2 Credits.**
An undergraduate research experience in chemistry or a closely related field for students in the Chemistry Department Honors Program, consisting of experimental or theoretical work on a topic developed in consultation with the faculty research advisor. A minimum of 4 credit hours must be accumulated to satisfy Chemistry Department Honors requirements, and 3 of those credit hours will satisfy the Capstone requirement. This course may be taken up to 4 times for a maximum of 4 credit hours. At the completion of the research, a written thesis, and an oral defense of the thesis, will be required. Prerequisite: Acceptance to the Chemistry Department Honors Program; CHEM 201, or CHEM 201 concurrently, or documentation of appropriate laboratory safety training.

**CHEM 700. Responsible Scholarship in the Chemical Sciences. 1 Credits.**

A course for beginning graduate students with particular emphasis on scholarship issues relevant to the chemical sciences. Topics will include scientific ethics, codes of conduct, record keeping, authorship, and the responsibilities of a scientist. Group discussions, particularly centered around case studies, will be a significant component of the course.

**CHEM 701. Laboratory Safety in the Chemical Sciences. 1 Credits.**

A course for beginning graduate students focusing on chemical safety in modern laboratories. The course will feature practical instruction in lab safety, an introduction to safety resources, and group discussions centered around case studies.

**CHEM 718. Mathematical Methods in Physical Sciences. 3 Credits.**

Review of all complex variable theory; introduction to the partial differential equations of physics; Fourier analysis; and special functions of mathematical physics. (Same as PHSX 718.) Prerequisite: Two semesters of junior-senior mathematics.

**CHEM 720. Fundamentals and Methods of Analytical Chemistry. 3 Credits.**
An introductory graduate level course in analytical chemistry, in which the principles of electrochemistry, spectroscopy, and separation science are utilized to solve analytical problems in inorganic, organic and biochemistry. Prerequisite: An undergraduate course in analytical chemistry, a year of organic chemistry, and a year of physical chemistry.

**CHEM 730. Coordination and Organometallic Chemistry. 3 Credits.**

An examination of the basic foundations of coordination chemistry and organometallic chemistry including symmetry methods, bonding, magnetism, and reaction mechanisms. Prerequisite: Two semesters of organic chemistry and one semester of physical chemistry in which quantum chemistry is introduced. The latter course may be taken concurrently with CHEM 730.

**CHEM 740. Principles of Organic Reactions. 3 Credits.**
A consideration of the structural features and driving forces that control the course of chemical reactions. Topics will include acid and base properties of functional groups; qualitative aspects of strain, steric, inductive, resonance, and solvent effects on reactivity; stereo-chemistry and conformations; an introduction to orbital symmetry control; basic thermodynamic and kinetic concepts; and an overview of some important classes of mechanisms. Prerequisite: Two semesters of undergraduate organic and one semester of physical chemistry or concurrent enrollment.

**CHEM 742. Spectroscopic Identification of Organic Compounds. 3 Credits.**
The use of techniques such as infrared, nuclear magnetic resonance, and ultraviolet spectroscopy, and mass spectrometry for elucidating the structure of organic molecules. A lecture and workshop course. Prerequisite: CHEM 626 and CHEM 627.

**CHEM 750. Introduction to Quantum Mechanics. 3 Credits.**
An introduction to the basic principles of quantum theory relevant to atomic and molecular systems. Topics include operators and operator algebra, matrix theory, eigenvalue problems, postulates of quantum mechanics, the Schrodinger equation, angular momentum, electronic structure, molecular vibrations, approximation methods, group theory, and the foundations of spectroscopy. Prerequisite: Two semesters of physical chemistry.

**CHEM 760. Introduction to Chemistry in Biology. 3 Credits.**
A comprehensive introduction to the application of chemistry to address problems in biology at the molecular level. The fundamentals of biomolecules (nucleic acids, proteins, lipids and carbohydrates) and techniques of chemical biology research will be discussed. This course is offered at the 500 and 700 level with additional assignments at the 700 level. Not open to students with credit in CHEM 560.

**CHEM 800. Research. 1-10 Credits.**
Original investigation on the graduate level.

**CHEM 810. Colloquium: _____. 1 Credits.**
Colloquia on various topics of current interest are presented by students, faculty, and visiting scientists.

**CHEM 816. Careers in the Biomedical Sciences. 1 Credits.**
Advanced course examining career options open to PhD scientists in the biomedical sciences, and providing preparation for the different career paths. Extensive student/faculty interaction is emphasized utilizing lectures, class discussion of assigned readings, and oral presentations. Graded on a satisfactory/unsatisfactory basis. (Same as BIOL 816 and PHCH 816.) Prerequisite: Permission of instructor.

**CHEM 817. Rigor, Reproducibility and Responsible Conduct in Research. 3 Credits.**
This class addresses the recognized problems in rigor, reproducibility, and transparency that are plaguing modern science. Students will learn the fundamentals of hypothesis design, avoiding bias, randomization, sampling, and appropriate statistical analyses, reagent validation, among other key topics. This course also introduces principles for being an ethical, responsible, and professional research scientist. Topics include: plagiarism, fabrication and falsification of data, record keeping and data sharing, mentor/mentee and collaborative relationships, among others. The class will include a mixture of lecture, case studies and discussion. (Same as BIOL 817/MDCM 817/PHCH 817.) Prerequisite: Graduate student.

**CHEM 820. Analytical Separations. 3 Credits.**
An advanced treatment of analytical separations techniques. The theory of separation science will be augmented with discussion of practical aspects of instrumentation and experiment design. Prerequisite: CHEM 720.

**CHEM 822. Electrochemical Analysis. 3 Credits.**
An advanced treatment of selected electroanalytical techniques and methodology. Prerequisite: CHEM 720.

**CHEM 824. Spectrochemical Methods of Analysis. 3 Credits.**
General concepts of encoding chemical information as electromagnetic radiation; major instrumental systems for decoding, interpretation, and presentation of the radiation signals; atomic emission, absorption, and fluorescence; ultraviolet, visible, infrared, and microwave absorption; molecular luminescence; scattering methods; mass spectrometry; magnetic resonance; automated spectrometric systems. Prerequisite: CHEM 720.

**CHEM 826. Mass Spectrometry. 3 Credits.**
An introduction to mass spectrometry. The various ionization techniques and mass analyzers will be discussed, and many examples of different mass spectrometric applications will be introduced. Prerequisite: CHEM 720.

**CHEM 828. Bioanalysis. 3 Credits.**
A course covering important aspects in modern chemical measurement with particular emphasis placed on bioanalysis. This course will survey the modern analytical challenges associated with the ongoing efforts in genomics and proteomics and discuss future trends in methods in instrumentation. Prerequisite: CHEM 720.

**CHEM 830. Structure, Bonding and Spectroscopic Methods in Inorganic Chemistry. 3 Credits.**

An introduction of quantum and group theories in relation to bonding and physicochemical properties of inorganic substances. Topics include vibrational and electronic spectroscopies, magnetism, and inorganic photochemistry. Prerequisite: CHEM 730.

**CHEM 832. Inorganic Reaction Mechanisms and Catalysis. 3 Credits.**
Mechanistic aspects of transition metal chemistry including substitution reactions, electron transfer reactions, rearrangement reactions, ligand reactions and inorganic photochemistry. Principles and applications of heterogeneous and homogeneous catalytic processes emphasizing catalysis at transition metal centers. Prerequisite: CHEM 730.

**CHEM 840. Physical Organic Chemistry. 3 Credits.**
An examination of the methods used to probe the mechanisms of organic reactions and of the chemistry of some important reactive intermediates. Topics will include isotope effects, kinetics, linear free energy relationships, solvent effects, a continuing discussion of orbital symmetry, rearrangements, carbocations, carbanions, carbenes, radicals, excited states, and strained molecules. Prerequisite: CHEM 740.

**CHEM 842. Organic Synthesis I. 3 Credits.**
A discussion of fundamental reactions for the formation of carbon-carbon bonds, oxidation, reduction, and functional group interchange. Prerequisite: CHEM 740.

**CHEM 844. Problem Solving in Organic Chemistry. 1 Credits.**
A course designed to develop a student's ability to apply fundamental concepts of mechanistic organic and organometallic chemistry, physical organic chemistry, bioorganic chemistry, synthetic organic reactions and techniques for structure elucidation. Students will propose solutions to practice problems mimicking challenges that arise in contemporary research in organic chemistry. The format includes interactive problem-solving discussions led by faculty and peers and monthly written examinations. May be repeated up to three times until the student has passed at least four of the written exams. Graded on a satisfactory/unsatisfactory basis. Prerequisite: CHEM 740 or permission of instructor.

**CHEM 850. Advanced Quantum Mechanics. 3 Credits.**
The advanced mathematical and physical principles of quantum mechanics relevant to atomic and molecular systems. Topics may include abstract vector spaces and representations, time-dependent quantum dynamics, electronic structure theory, density matrices, second-quantization, advanced group theory, path integrals, and scattering theory. Prerequisite: CHEM 750 or its equivalent.

**CHEM 852. Statistical Thermodynamics. 3 Credits.**
Thermodynamics and introduction to equilibrium statistical mechanics with emphasis on problems of chemical interest. The course consists of two roughly equal parts: 1) An advanced overview of the laws and concepts of thermodynamics with application to specific problems in phase and chemical equilibria and 2) An introduction to equilibrium statistical mechanics for both classical and quantum systems. Prerequisite: CHEM 750 or its equivalent.

**CHEM 854. Chemical Kinetics and Dynamics. 3 Credits.**
A study of the rates, mechanisms, and dynamics of chemical reactions in gases and liquids. Topics include an advanced overview of classical kinetics, reaction rate theories (classical collision theory, transition-state theory and introductory scattering theory), potential energy surfaces, molecular beam reactions, photochemistry, Marcus electron transfer theory and other areas of current interest. Prerequisite: CHEM 750 or its equivalent.

**CHEM 856. Molecular Spectroscopy. 3 Credits.**
Quantitative molecular spectroscopy and its chemical applications. The basic principles of the molecular energy levels, selection rules and spectral transition intensities will be discussed and applied to rotational, vibrational, electronic, and nuclear magnetic spectroscopy. Linear and nonlinear spectroscopies will be addressed. Prerequisite: CHEM 750 or its equivalent.

**CHEM 860. Principles and Practice of Chemical Biology. 3 Credits.**

A survey of topics investigated by chemical biology methods including: transcription and translation, cell signaling, genetic and genomics, biochemical pathways, macromolecular structure, and the biosynthesis of peptides, carbohydrates, natural products, and nucleic acids. Concepts of thermodynamics and kinetics, bioconjugations and bioorthogonal chemistry will also be presented. (Same as BIOL 860, MDCM 860 and PHCH 860.) Prerequisite: Permission of instructor.

**CHEM 899. Master's Thesis. 1-10 Credits.**
Research work (either experimental or theoretical) in chemistry for students working toward the M.S. degree. Graded on a satisfactory progress/limited progress/no progress basis.

**CHEM 900. Advanced Research. 1-10 Credits.**
Original investigation in chemistry at the graduate level. Graded on a satisfactory/unsatisfactory basis. Prerequisite: Advancement to doctoral candidacy.

**CHEM 914. Computational Methods in Physical Sciences. 3 Credits.**
Advanced computer applications in physical science. General discussion and illustration of problem organization and solution by numerical and other methods with examples from physics, astronomy, and other physical sciences. Students will design, write, validate, and document computer programs to solve physical problems. (Same as ASTR 815 and PHSX 815.) Prerequisite: Six hours of computer science courses numbered 300 or above, and six hours of physics and/or astronomy courses numbered 300 or above.

**CHEM 930. Bioinorganic Chemistry. 3 Credits.**
A survey of metalloproteins and metalloenzymes, their structures and functions, including recent advances in biomimetic modeling, small molecule activation in biological systems, and related physical methods. Prerequisite: CHEM 832.

**CHEM 942. Organic Synthesis II. 3 Credits.**
A survey of important techniques in organic chemistry with respect to scope, limitations, mechanism, and stereochemistry. Emphasis will be placed on new synthetic methods and application of such methods to the synthesis of structurally interesting compounds, particularly natural products. Prerequisite: CHEM 842.

**CHEM 950. Advanced Statistical Mechanics. 3 Credits.**
Advanced equilibrium statistical mechanics and introduction to nonequilibrium statistical mechanics. Topics include: the theory of liquids, critical phenomena linear response theory and time correlation functions, Langevin dynamics, and molecular hydrodynamics. (Same as PHSX 971.) Prerequisite: CHEM 909 or equivalent.

**CHEM 980. Advanced Topics in Chemistry: _____. 2-3 Credits.**
A course covering special advanced topics in chemistry not included in other graduate courses. One or more topics will be covered in a given semester and an announcement of the course content and prerequisites will be made at the end of the previous semester. This course may be taken more than once when the topic varies.

**CHEM 999. Doctoral Dissertation. 1-10 Credits.**
Research work (either experimental or theoretical) in chemistry for students working toward the Ph.D. degree. Graded on a satisfactory progress/limited progress/no progress basis.