CHEMISTRY AND BIOCHEMISTRY

College of Science and Engineering
Dean: Keith Bowman

Department of Chemistry and Biochemistry
TH 806
Phone: 415-338-1288
Chair: Jane DeWitt
Graduate Coordinators: Andrew Ichimura, Bruce Manning

Program Scope and Career Outlook
The Department of Chemistry and Biochemistry offers an outstanding educational environment for undergraduate and graduate students. Our mission is to educate, train, and produce versatile chemists and biochemists that understand both the theoretical basis and practical applications of their discipline. Department faculty provide quality instruction across a wide range of sub-disciplines. Our degree programs are designed to prepare students for various professional positions (i.e., biotechnology and pharmaceutical companies, chemical manufacturing, and other laboratory-based industries), health professions (i.e., medical, pharmacy, and dental school), graduate study, and teaching positions.

Students receive significant hands-on experience with modern instrumentation in our relatively small-sized lab classes, and the opportunity to participate in research projects under the direct supervision of our faculty. The department houses a variety of state-of-the-art research instrumentation, laboratory facilities, and computational labs. These include a Nuclear Magnetic Resonance (NMR) facility, a Mass Spectrometry (MS) facility, a Scanning Electron Microscopy (SEM) facility and the Computational Chemistry and Visualization (CCV) laboratory.

The Bachelor of Arts in Chemistry program is particularly well-suited for those students whose career goals involve the integration of chemistry with other fields. This program can be combined with another degree or minor to develop the unique synthesis of experience needed for careers in health professions, forensic science, environmental science, regulatory affairs, chemical engineering, patent law, management, sales, marketing, technical writing, scientific journalism, library science, and art restoration. This program also provides excellent preparation for high school science teachers. Students planning to become K-12 chemistry or science teachers should note that additional preparation beyond the major is required to meet the breadth requirements and should consult with the credential advisor in the Department of Chemistry and Biochemistry to review the state-mandated requirements.

The Bachelor of Science in Chemistry program offers a comprehensive education leading to a professional degree in chemistry. The program includes hands-on training in laboratory and instrumental techniques. Students are required to meet the breadth requirements and should consult with the credential advisor in the Department of Chemistry and Biochemistry to review the state-mandated requirements.

The Bachelor of Science in Biochemistry is designed for students who wish to be particularly well qualified at the rapidly expanding interface between biology and chemistry. The degree includes extensive laboratory training, provides exceptional preparation for careers in biotechnology, and enjoys a favorable reputation among biotechnology companies in the Bay Area. This degree also provides a strong foundation for a graduate degree in biochemistry.

The Master of Science degree in Chemistry and the Master of Science degree in Biochemistry are programs of study with research at the core. As the student focuses in depth on an independent scientific investigation, solid research and communication skills are developed. The goal of both M.S. degree programs is to provide students with a thorough grounding in laboratory and research skills, and in-depth training in their areas of specialization. Our M.S. program provides excellent training for
1. careers in all aspects of the chemical industry (biotechnology, environment, process and analytical, basic research);
2. science educators seeking to increase their skill and knowledge base; and
3. students whose goal is advanced study at the Ph.D. level.

The M.S. in Chemistry program is approved by the ACS.

Significant features of our department include high-quality teaching, one-on-one advising for all of our majors, and opportunities for students to participate in research under the direct supervision of active faculty members who are recognized authorities in their field. Students interested in becoming involved in research should consult with an advisor and review faculty research interests on our department website (www.chembiochem.sfsu.edu (http://www.chembiochem.sfsu.edu)). Examples of research projects currently under investigation by our faculty members and their research students include:

Analytical Chemistry
Identification and quantitation of organic pollutants via Gas Chromatography/Mass Spectrometry (GC/MS) and Direct Sampling Mass Spectrometry (DSMS). Application of X-Ray Fluorescence spectrometry (XRF) to the determination of toxic elements in foods, supplements, and other products. Development of novel analytical techniques for separation and detection of redox-sensitive trace species.

Biochemistry
Biophysical Chemistry

Biophysical spectroscopic methods, including nanosecond time-resolved polarized absorption spectroscopy, to characterize biological function and examine the molecular basis of disease. Chromatin folding, dynamics and stability.

Chemical Education

Identify student experiences and instructional practices that promote student success in chemistry courses and persistence in STEM majors. Design experiences to engage students in applying course-based chemistry knowledge to address community questions and societal needs.

Environmental Chemistry

Detection of trace levels of volatile organic compounds and heavy metals in urban air, water, and soil samples. Determination of structures and speciation of metals and trace elements adsorbed on environmental surfaces by X-ray absorption spectroscopy. Modeling speciation, precipitation, and adsorption reactions of trace elements in environmental systems. Development and characterization of reactive metallic and mineral-based remediation materials for soil and water contaminants. Investigation of the composition and degradation of organic matter in marine systems through quantification and modeling of natural carbon isotopes.

Organic/Bioorganic Chemistry


Materials and Inorganic Chemistry

Synthesis and characterization of semiconducting thin films with applications to solar cells, water splitting, water remediation and CO2 reduction. Growth and nucleation of crystalline TiO2 by atomic force microscopy (AFM) and in situ grazing incidence X-ray diffraction (GIXRD). Computational approaches to speed the development of solid-state batteries, photocatalysts, and quantum computers using Density Functional Theory and molecular dynamics.

Natural Products Chemistry

Isolation and characterization of novel compounds from marine microorganisms from sediments, algae and sponges with anti-cancer, or anti-malarial properties.

Physical Chemistry

Synthesis and characterization of heteroatom substituted zeolites by XRD, solid state MAS-NMR, and optical spectroscopy, with applications to photocatalysis of carbon dioxide to fuels. Photophysics and electron spin resonance (ESR) investigation of thin films for applications in photovoltaics and photocatalysis.

Professors

DeWitt, Erden, Esquerra, Gassner, Gerber, Manning, Palmer, Simonis, Wu

Associate Professors

Amagata, Anderson, Baird, Guliaev, Ichimura, Komada

Assistant Professors

Adelstein, Billingsley, Eroy-Reveles, Kuhn

Research Associate Professor

Yen

Adjunct Professor

Runquist

Majors

• Bachelor of Arts in Chemistry (bulletin.sfsu.edu/past-bulletin-archive/2016-2017/colleges/science-engineering/chemistry-biochemistry/ba-chemistry)
• Bachelor of Science in Chemistry (bulletin.sfsu.edu/past-bulletin-archive/2016-2017/colleges/science-engineering/chemistry-biochemistry/bs-chemistry)
• Bachelor of Science in Biochemistry (bulletin.sfsu.edu/past-bulletin-archive/2016-2017/colleges/science-engineering/chemistry-biochemistry/bs-biochemistry)

Minors

• Minor in Chemistry (bulletin.sfsu.edu/past-bulletin-archive/2016-2017/colleges/science-engineering/chemistry-biochemistry/minor-program-chemistry)

Masters

• Master of Science in Chemistry (bulletin.sfsu.edu/past-bulletin-archive/2016-2017/colleges/science-engineering/chemistry-biochemistry/ms-chemistry)
• Master of Science in Chemistry: Concentration in Biochemistry (bulletin.sfsu.edu/past-bulletin-archive/2016-2017/colleges/science-engineering/chemistry-biochemistry/ms-chemistry-concentration-biochemistry)

CHEM 100 Preparation for Chemistry (Units: 3)

Elementary concepts of chemistry. Development of skills in applying mathematics to solving problems in chemistry. Preparation for CHEM 115 or CHEM 180. (Plus-minus ABC/NC grading only)

CHEM 101 Survey of Chemistry (Units: 3)

Prerequisite: 50 or higher on ELM or exemption, or grade of C or better in MATH 70/ESM 70. High school chemistry recommended. Principles of general and organic chemistry and biochemistry. Suitable for pre-nursing, exercise science and health science majors. Not for CHEM 115 preparation.

Course Attributes:

• B1: Physical Science

CHEM 102 Survey of Chemistry Laboratory (Unit: 1)

Laboratory to accompany or follow CHEM 101. Extra fee required. (Charges for missing or damaged laboratory locker items apply.)

Course Attributes:

• B3: Lab Science
CHEM 109 Fundamentals of Food Chemistry: Natural Constituents and Additives (Units: 3)
Chemical composition of foods including sugars, starches, fats, and oils; protein, vitamins, and minerals; additives used in food; government role in food processing and distribution.

CHEM 110 Fundamentals of Food Chemistry: Natural Constituents and Additives Laboratory (Unit: 1)
Prerequisite: Must be taken concurrently with CHEM 109. Laboratory to accompany CHEM 109. Hands-on experience in assessing food constituents using modern chemical methods and techniques including chemical instrumentation. (Charges for missing or damaged laboratory locker items apply.)

CHEM 115 General Chemistry I: Essential Concepts of Chemistry (Units: 5)
Prerequisites: CHEM 100 with a grade of C or better (letter grade only) or satisfactory score on chemistry placement exam. Score of 50 or above on ELM or approved exemption, or MATH 70 with a grade of C or better or ESM 70 with grade of CR.

CHEM 130 General Organic Chemistry (Units: 3)
Prerequisite: CHEM 115 with a grade of C or better.

CHEM 180 Chemistry for the Energy and the Environment (Units: 3)
Prerequisites: MATH 70 with a grade of C or better, or 50 or higher or ESM 70 with grade of CR.

Chemical concepts of atomic properties, atomic interactions, reaction chemistry, stoichiometry, thermodynamics, chemical kinetics, and equilibria. (Charges for missing or damaged laboratory locker items apply.)

CHEM 215 General Chemistry II: Quantitative Applications of Chemistry Concepts (Units: 3)
Prerequisites: CHEM 115 with a grade of C or better.

Quantitative aspects of chemistry with an emphasis on kinetics, equilibria (acid-base, solubility and buffer), thermodynamics, and electrochemistry.

CHEM 216 General Chemistry II Laboratory: Quantitative Applications of Chemistry Concepts (Units: 2)
Prerequisite: C or better in CHEM 215 or concurrent enrollment. Determination of thermodynamic quantities; rate laws; acid dissociation constants; preparation and analysis of buffer solutions; synthesis and analysis of a molecular complex. Laboratory. (Charges for missing or damaged laboratory locker items apply.) Extra fee required.

CHEM 233 Organic Chemistry I (Units: 3)
Prerequisites: CHEM 115 and CHEM 215 with grades of C or better. Priority enrollment for students majoring in chemistry and biochemistry. Other majors may enroll on a space available basis.

Principles of organic chemistry emphasizing the structure, properties and reactions of alkanes, cycloalkanes, alkyl, halides, alcohols, ethers and alkenes; stereochemistry; mechanisms of substitution and elimination reactions. Primarily for students majoring in chemistry and biochemistry. [Formerly CHEM 333. CHEM 233 is not open to students who have completed CHEM 333.]

CHEM 234 Organic Chemistry I Laboratory (Units: 2)
Prerequisite: CHEM 233 or 130 with grade of C or better, or concurrent enrollment in either.

Techniques and selected experiments in organic chemistry. (Charges for missing or damaged laboratory locker items apply.)

CHEM 300 General Physical Chemistry I (Units: 3)
Prerequisites: CHEM 321 [formerly CHEM 320], CHEM 335, MATH 227, and PHYS 121 or PHYS 230 or PHYS 240, each with a grade of C or better; or consent of instructor. Concurrent enrollment in CHEM 351 is strongly encouraged. Integrated mathematics and physics for physical chemistry, fluids, wave motion, or thermodynamics, partial derivatives, multiple integrals, introductory vector calculus, introductory differential equations. (Plus-minus letter grade only)

CHEM 301 General Physical Chemistry II (Units: 3)
Prerequisite: CHEM 300 with a grade of C or better or consent of instructor. Concurrent enrollment in CHEM 340 or CHEM 349.

Quantum mechanics, spectroscopy, biophysical spectroscopy, intermolecular forces, macromolecules, and statistical thermodynamics.

CHEM 321 Quantitative Chemical Analysis (Units: 3)
Prerequisites: CHEM 215 and CHEM 216, with grades of C or better. For chemistry, biochemistry, and biology majors.

Foundation course in analytical chemistry with focus on quantitative analysis. Topics include uncertainties, statistics, equilibrium, titrimetric methods, electrochemistry and potentiometry, molecular and atomic spectroscopy, mass spectrometry, and chromatography. (Plus-minus letter grade only.) [Formerly CHEM 320]
CHEM 322 Quantitative Chemical Analysis Laboratory (Units: 2)
Prerequisite: Concurrent enrollment in CHEM 321, or grade of C or better in CHEM 321. For chemistry, biochemistry, and biology majors.

Practical experience in performing accurate and precise measurements of chemical species in a variety of real world samples using gravimetric, titrimetric, potentiometric, spectroscopic, and chromatographic methods. Students who have taken CHEM 320 cannot take CHEM 321/CHEM 322 for credit. (Plus-minus letter grade only) (Charges for missing or damaged laboratory locker items apply.) Extra fee required.

CHEM 325 Inorganic Chemistry (Units: 3)
Prerequisites: CHEM 215 and CHEM 335 with grades of C or better. For chemistry, biochemistry, and biology majors.

Theories of chemical bonding and their application to inorganic systems with emphasis on transition metal complexes. Molecular symmetry, acid/base, redox and solid-state chemistry; introduction to organometallic and bioinorganic chemistry. [Formerly CHEM 425]

CHEM 327 Practical GC and HPLC (Units: 4)
Prerequisites: Grades of C or better in CHEM 234 [formerly CHEM 334], CHEM 321, and CHEM 322.

Theory, hardware and experience in GC and HPLC separations. Emphasis on practical skills and common applications in natural products, environmental, and pharmaceutical analyses. (Plus-minus letter grade only) (Charges for missing or damaged laboratory locker items apply.) Extra fee required.

CHEM 335 Organic Chemistry II (Units: 3)
Prerequisite: CHEM 233 (formerly CHEM 333) with grade of C or better.

Continuation of CHEM 233.

CHEM 336 Organic Chemistry II Laboratory (Units: 2)
Prerequisites: CHEM 234 [formerly CHEM 334] with grade of C or better; CHEM 335 with grade of C or better or concurrent enrollment.

Techniques and experiments in organic synthesis, isolation, purification and characterization. Intended for science majors. Activity, 1 unit; Laboratory, 1 unit. Extra fee required. (Charges for missing or damaged laboratory locker items apply.)

CHEM 338 Organic Chemistry II: Laboratory Honors (Units: 3)
Prerequisites: CHEM 233 [formerly CHEM 333] and CHEM 234 [formerly CHEM 334], each with grade of B or better. Must be taken concurrently with CHEM 335. Substitute for CHEM 336.

Experiments in organic synthesis and analysis plus a research project directed by faculty. (Charges for missing or damaged laboratory locker items apply.) Classwork, 1 unit; laboratory, 2 units. Extra fee required. (Plus-minus letter grade only)

CHEM 340 Biochemistry I (Units: 3)
Prerequisites: CHEM 215, CHEM 233 (formerly CHEM 333), and CHEM 335 with grades of C or better. For chemistry, biochemistry, and biology majors.

Protein structure and function; carbohydrate metabolism; enzyme kinetics and thermodynamics; electron transport chain.

CHEM 341 Biochemistry II (Units: 3)
Prerequisite: CHEM 340 with a grade of C or better.

Biosynthesis and degradation of lipids, amino acids, and nucleotides; protein synthesis, folding and degradation; DNA and RNA structure; DNA replication and transcription.

CHEM 343 Biochemistry I Laboratory (Units: 3)
Prerequisites: Grade of C or better in CHEM 216 and CHEM 234 [formerly CHEM 334], CHEM 340 or CHEM 349 (or concurrent enrollment in CHEM 340 or CHEM 349). CHEM 321 recommended. Priority registration for biochemistry and chemistry majors.

Chemical and enzymatic experiments involving proteins, carbohydrates, and nucleic acids with emphasis on enzyme kinetics. Utilization of standard and modern biochemical techniques. (Charges for missing or damaged laboratory locker items apply.) Classwork, 1 unit; laboratory, 2 units. Extra fee required. (Plus-minus letter grade only)

CHEM 349 General Biochemistry (Units: 3)
Prerequisites: CHEM 115 and CHEM 215, and CHEM 130 or CHEM 335, each with a grade of C or better. Not for biochemistry or chemistry BS majors.

Survey of major areas in biochemistry including enzymology, biochemical energetics, and carbohydrate, lipid and nucleic acid metabolism. Students who have completed CHEM 340 may not take CHEM 349 for credit.

CHEM 351 Physical Chemistry I: Thermodynamics and Kinetics (Units: 3)
Prerequisites: Upper division standing; CHEM 233, CHEM 251 (may be taken concurrently), and CHEM 321, each with a grade of C or better, or consent of the instructor.

Thermodynamics and kinetic theory. Classwork, 2 units; activity, 1 unit.

CHEM 353 Physical Chemistry II: Quantum Chemistry and Spectroscopy (Units: 3)
Prerequisite: CHEM 233, CHEM 251, and CHEM 321, each with a grade of C, or better or consent of instructor; upper division standing.

Quantum chemistry, spectroscopy of atoms and molecules, statistical thermodynamics. Classwork, 2 units; activity, 1 unit.

CHEM 357 Computer Applications in Chemistry and Biochemistry (Units: 3)
Prerequisite: CHEM 321 [formerly CHEM 320] and CHEM 233 [formerly CHEM 333], each with grade of C or better.

Data acquisition, manipulation, and presentation with emphasis on software used in chemistry and biochemistry laboratories. Computational chemistry and molecular visualization software for small and large molecules. Development of interactive molecular visualization web pages. Classwork, 2 units; laboratory, 1 unit.

CHEM 380 Chemistry Behind Environmental Pollution (Units: 3)
Prerequisite: CHEM 115 or CHEM 180 with a grade of C- or better.

Traditional and contemporary topics in environmental chemistry. Understanding and appreciation of various chemical processes and principles underlying environmental problems facing society.

Course Attributes:
- UD-B: Physical Life Science
- Environmental Sustainability
CHEM 390GW Contemporary Chemistry and Biochemistry Research - GWAR (Units: 3)
Prerequisites: Upper division standing; chemistry or biochemistry major; ENG 214 or ENG 215; and CHEM 321 or CHEM 335, each with a grade of C or better.

Improve skills in written and oral communication with an emphasis on the communication skills expected of chemists and biochemists in their professional activities. Classwork, 2 units; laboratory, 1 units. (ABC/NC grading only)
Course Attributes:
- Graduation Writing Assessment

CHEM 399 Careers in Chemistry and Biochemistry (Unit: 1)
Prerequisite: Senior standing.

Discussion of the full spectrum of careers in chemistry and biochemistry: career counseling, resume and interview guidance and strategies, outside speakers from education and industry. (CR/NC grading only)

CHEM 420 Environmental Analysis (Units: 3)
Prerequisites: CHEM 321 and CHEM 322, each with grade of C or better.

Practical analysis of real world samples and environmental pollutants. Statistics, QA/QC, heavy metal analysis via atomic spectroscopy, and organic pollutant analysis via GC/MS. (Charges for missing or damaged laboratory locker items apply.) Classwork, 2 units; laboratory, 1 unit. Extra fee required. (Plus-minus letter grade only)

CHEM 422 Instrumental Analysis (Units: 4)
Prerequisites: CHEM 321 and CHEM 322, each with grade of C or better.

Instrumental methods for chemical and biochemical analysis including basic electronics, molecular and atomic spectroscopy, IR and Raman spectroscopy, mass spectrometry, and chromatography. (Charges for missing or damaged laboratory locker items apply.) Classwork, 2 units; laboratory, 1 unit. Extra fee required. (Plus-minus letter grade only)

CHEM 426 Advanced Inorganic Chemistry Laboratory (Units: 2)
Prerequisites: CHEM 321, CHEM 322, and CHEM 325, each with a grade of C or better or consent of the instructor.

Modern techniques in inorganic chemistry with an emphasis on synthesis, characterization, and reactivity of metals in a variety of materials including biological and environmental samples. (Charges for missing or damaged laboratory locker items apply.) Extra fee required.

CHEM 433 Advanced Organic Chemistry (Units: 3)
Prerequisite: CHEM 335 with a grade of C or better. Concurrent registration in or completion of CHEM 301 or CHEM 353 is required.

Theoretical aspects of organic chemistry, molecular structure, and reaction mechanisms.

CHEM 443 Biophysical Chemistry Laboratory (Units: 4)
Prerequisites: CHEM 343 with grade of C or better; prior or concurrent enrollment in CHEM 301 or 353.

Experiments using modern techniques in biochemistry, bioinformatics, molecular biology and biophysics for the study of biological macromolecules. (Charges for missing or damaged laboratory locker items apply.) Classwork, 2 units; laboratory, 2 units. Extra fee required. (Plus-minus letter grade only)

CHEM 451 Experimental Physical Chemistry Laboratory (Units: 2)
Prerequisites: CHEM 321 and CHEM 322; CHEM 351 and CHEM 353 (or CHEM 300 and CHEM 301), each with a grade of C or better, or consent of instructor.

Emphasis on molecular spectroscopy, thermodynamics, kinetics, electrochemistry, applications of computational chemistry, and error analysis. 2 laboratory periods per week. Extra fee required. (Plus-minus letter grade only) (Charges for missing or damaged laboratory locker items apply.)

CHEM 470 Research (Units: 3)
Prerequisites: One year each of general and organic chemistry and consent of instructor and faculty research adviser.

Intended for motivated students interested in independent research. Requires 6-9 hours of research each week, lecture attendance, formal poster presentation, and written report. May be repeated for a total of 6 units.

CHEM 640 Advanced Topics in Biochemistry (Units: 3)
Prerequisites: CHEM 349, or CHEM 341, or CHEM 340 and BIOL 350, each with a grade of C or better or consent of the instructor.

Topic to be specified in Class Schedule. May be repeated as topics vary.

CHEM 645 Research Trends in Chemistry and Biochemistry (Units: 3)
Prerequisite: GPA of 3.0 or better, CHEM 340 and one semester of physical chemistry.

Self-directed learning experience for undergraduates in modern research topics in chemistry and biochemistry.

CHEM 680 Chemical Oceanography (Units: 3)
Prerequisite: CHEM 215 or equivalent.

Investigation of the composition and dynamics of the ocean through chemistry. (Plus-minus letter grade only)

CHEM 685 Projects in the Teaching of Chemistry and Biochemistry (Unit: 1)
Prerequisites: Consent of instructor and grade of B or better in course in which student will be instructing.

Instructional methods and techniques for effective student teaching, leading class discussions and activities and carrying out class demonstrations. May be repeated for a total of 4 units.

CHEM 694 Cooperative Education in Chemistry (Unit: 1)
Prerequisite: Upper division standing or consent of instructor.

Supervised chemistry laboratory experience in industry. Enrollment by prior arrangement with supervising faculty member and industry sponsor. See department adviser for details. A final written report is required. May be repeated for a total of 3 units for credit.

CHEM 699 Independent Study (Units: 1-6)
Prerequisites: Consent of the department and the instructor concerned.

Laboratory or library research work focused on chemistry and biochemistry problems directed by a department faculty. For advanced, superior students majoring or minoring in chemistry or biochemistry. Final written report required. May be repeated.
CHEM 741 Electron Microscopy (Units: 4)
Prerequisite: Graduate or senior standing, and consent of instructor.
Preparation of biological and inorganic materials for scanning and transmission electron microscopy, x-ray microanalysis, EBSD, CL, operation of the electron microscope(s), and data interpretation. Classwork, 1 unit; laboratory, 3 units. Extra fee required. (This course is offered as BIOL 741, CHEM 741, and ERTH 741. Students may not repeat the course under an alternate prefix.)

CHEM 800 Special Topics in Chemistry (Units: 3)
Prerequisite: Graduate standing in chemistry or consent of instructor.
Topic to be specified in Class Schedule. May be repeated as topics vary.

CHEM 820 NMR Applications and Techniques (Units: 3)
Prerequisites: Classified graduate standing in chemistry or consent of instructor.
FT NMR concepts and operating techniques; 1D and 2D experiments; relaxation and dynamics. Spectral interpretation. Classwork, 2 units; laboratory, 1 unit.

CHEM 821 Mass Spectrometry - Principles and Practice (Units: 3)
Prerequisite: Classified graduate standing in chemistry or consent of instructor.
Fundamental principles and modern practice of mass spectrometry, instrumentation (mass analyzers, ionization modes, sample introduction systems) and applications (qualitative and quantitative analysis, environmental and biomedical applications). (Plus-minus letter grade only)

CHEM 832 Organic Synthesis (Units: 3)
Prerequisite: Classified graduate standing in chemistry or consent of instructor.
Problems relating to current organic synthetic methods. Synthesis and reactions of the major classes of mono- and polyfunctional compounds.

CHEM 834 Organic Spectroscopic Methods (Units: 3)
Prerequisites: Classified graduate standing in chemistry; CHEM 301 or CHEM 353, or consent of instructor.
Relations between molecular structure and spectroscopic behavior. Mass spectrometry, infrared, electronic and magnetic resonance spectroscopy.

CHEM 841 Enzymology (Units: 3)
Prerequisites: Classified graduate standing in chemistry and CHEM 341 and CHEM 301 or 353, or consent of instructor.
The relationships between enzyme structure and catalytic activity, including enzyme kinetics and mechanisms.

CHEM 842 Bioorganic and Medicinal Chemistry (Units: 3)
Prerequisite: Classified graduate status in chemistry or consent of instructor.
Molecular recognition, enzymatic reaction mechanisms, catalytic antibodies/polymers, enzymes in organic synthesis, pharmacodynamics, and drug action, drug design for pharmacokinetic problems.

CHEM 846 Biology and Chemistry of Signaling Pathways (Units: 3)
Prerequisite: Classified graduate status or consent of instructor.
An interdisciplinary presentation of the mechanisms by which extracellular stimuli trigger intracellular biochemical reactions that lead to alterations in cellular function. (This course is offered as BIOL 732 and CHEM 846. Students may not repeat the course under an alternate prefix.)

CHEM 850 Valency and Spectroscopy (Units: 3)
Prerequisite: Classified graduate standing in chemistry and passing score on the ACS diagnostic examination in quantum chemistry, or consent of instructor.
Quantum mechanics of atomic and molecular structure using computers and group theory. Elementary microwave, infrared, optical, and magnetic resonance spectroscopy.

CHEM 851 Biochemical Spectroscopy (Units: 3)
Prerequisites: Classified graduate standing in chemistry and passing ACS diagnostic examination in quantum chemistry, a biochemistry course, or consent of instructor.
Quantum chemistry elements. Principles, techniques, and biochemical applications of spectroscopy.

CHEM 852 Statistical Mechanics: Molecular Relaxation (Units: 3)
Prerequisites: CHEM 351, CHEM 353, or equivalent. Ensembles in statistical thermodynamics. Irreversible statistical mechanics and correlation functions. Brownian motion. Relaxation processes probed by dynamic light scattering, hydrodynamics, magnetic resonance, and transient electric birefringence.

CHEM 870 Computational Methods in Chemistry (Units: 3)
Prerequisites: Upper division or graduate standing; one year of undergraduate physical chemistry.
Introduction to quantum chemical and classical mechanical methods for the computation of molecular structure, molecular spectroscopy, liquid state transport properties and molecular reactivity for small and large molecules, including solids and interactions at surfaces. Hands on use of four software packages: Gaussian 09, AMBER molecular dynamics, LAMMPS dynamics for mesoscopic systems, and BEST for molecular hydrodynamics. (Plus-minus letter grade only)

CHEM 880 Seminar (Units: 3)
Prerequisite: Classified graduate standing in chemistry or consent of instructor.
Exploration of current areas and methods of chemical research. Oral presentations and scientific writing. Should be taken during the first year of graduate work.

CHEM 885 Teaching College Chemistry (Units: 3)
Prerequisite: Graduate standing or consent of instructor.
Examination of the role of preparation, assessment, and feedback in teaching college-level chemistry laboratory and discussion sections; emphasis on effective classroom techniques and organizational strategies. (Plus-minus letter grade only)
**CHEM 895 Research Project (Units: 3)**
Prerequisite: Consent of instructor and approval of Advancement to Candidacy (ATC) and Culminating Experience (CE) forms by Graduate Studies.

Supervised independent and original laboratory investigation. Guidelines are available through the Department of Chemistry & Biochemistry. (CR/NC grading only)

**CHEM 897 Research (Units: 1-9)**
Prerequisites: Classified graduate standing in chemistry and CHEM 880 (may be taken concurrently), or consent of instructor. Independent and original laboratory, computational, or theoretical research under faculty supervision. Maximum of 9 units may be applied toward graduation.

**CHEM 898 Master's Thesis (Units: 3)**
Prerequisites: Consent of instructor and approval of Advancement to Candidacy (ATC) for the Master of Science in Chemistry and Culminating Experience (CE) forms by Graduate Studies. ATC and Proposal for Culminating Experience Requirement forms must be approved by the Graduate Division before registration. (CR/NC grading only)