

Department of

# Chemistry and Biochemistry

College of Science

**Head: Professor Steve Scheiner**, computational chemistry  
Office in Maeser Laboratory 140, (435) 797-1620

**FAX** (435) 797-3390

**E-mail** chemist@cc.usu.edu

**WWW** <http://www.chem.usu.edu>

**Trustee Professor** Ann E. Aust, biochemistry; **Professors** Steven D. Aust, biochemistry; Stephen E. Bialkowski, analytical chemistry; George H. Emert, biochemistry; David Farrelly, physical chemistry; Vernon D. Parker, physical organic chemistry; **Professors Emeritus** William M. Moore, physical chemistry; Richard K. Olsen, organic chemistry; Grant G. Smith, organic chemistry; Jack T. Spence, inorganic chemistry; **Associate Professors** Robert S. Brown, analytical chemistry; Bradley S. Davidson, organic chemistry; Scott A. Ensign, biochemistry; Alvan C. Hengge, organic chemistry; Richard C. Holz, bioinorganic chemistry; John L. Hubbard, inorganic chemistry; Lance C. Seefeldt, biochemistry; **Assistant Professors** Lisa M. Berreau, inorganic chemistry; Alexander I. Boldyrev, physical chemistry; Cheng-Wei Tom Chang, organic chemistry; John W. Peters, biochemistry; **Research Assistant Professor** Tapas Kar, physical chemistry

**Degrees Offered:** Bachelor of Science (BS), Bachelor of Arts (BA), Master of Science (MS), Doctor of Philosophy (PhD) in Chemistry; MS and PhD in Biochemistry; BS and BA in Chemistry Teaching; BS and BA in Composite Teaching—Physical Science (Chem)

**Undergraduate emphases:** BS—Professional Chemistry, Biochemistry, Chemical Education, Life Science; **Graduate specializations:** Chemistry—Analytical Chemistry, Inorganic Chemistry, Organic Chemistry, Physical Chemistry

## Undergraduate Programs

### Objectives

Chemistry is a subject that addresses the properties of materials and the transformations that they undergo. Especially important are aspects of energy and structure related to chemical reactivity. Consequently, students of many disciplines take courses in chemistry to learn about the behavior of the substances they will use or reference. The Department of Chemistry and Biochemistry offers a wide variety of courses for those whose majors and/or anticipated careers require a knowledge of chemistry. These areas of study include nutrition, engineering, biology, agriculture, natural resources, medicine, law, and education, to name a few. Many students also choose chemistry as an elective course to better prepare themselves as citizens in a technological world.

The **Bachelor of Science Degree** entails considerable specialization in chemistry and related areas. The BS emphases require a common core of courses, but allow for a different concentration of advanced work according to the interests and career objectives of the student. The **BS with Professional Chemistry Emphasis** and **BS with Biochemistry Emphasis** degrees meet the requirements for certification by the American Chemical Society (ACS). The

certified degree emphases provide excellent preparation for immediate entry into the job market or for graduate school in chemistry, biochemistry, chemical engineering, molecular biology, nutrition, food science, materials science, and a wide variety of other fields. ACS certification in **Chemical Education** is available to students who complete an ACS-certified program, together with the Professional Education program in secondary education. The **BS with Life Science Emphasis** degree is popular for students wishing to go on to medical or dental graduate programs. The life science emphasis is particularly appropriate for **premedical** and **predental** students who want a strong base for understanding the nature of chemical reactions in the body and the behavior of the drugs they will prescribe, or who want an attractive alternative should they decide ultimately not to pursue medical or dental school. The **Chemistry Teaching Major** or the **Composite Teaching Major in Physical Science** are available to those who want a career in secondary education. The BA degree is an excellent choice for students with an interest in studying **law** or **business** and who have an interest in science.

The core of the program utilizes year-long sequences of classes. The first-year sequence introduces the basic principles of chemistry, as well as most of the major concepts of the science. The second year explores in greater depth the characteristics of

carbon-based compounds that serve as the backbone for the chemistry of life; for most drugs and medicines; for petroleum; for most fibers, paints, and plastics; and for many other commercial products. The third year examines in greater depth the models, theories, and mathematical interpretation of the structures, rates of change, energetics, and other properties of chemicals. In addition, one-semester courses examining the chemistry of life processes, the behavior of inorganic substances, and the analysis of the composition of substances are required. Many of the sequences have associated laboratory courses where students get hands-on practice. Here they synthesize compounds, measure physical properties, analyze samples, and determine structural features of compounds, using modern techniques and instrumentation. The requirements of the BS and BA degrees in chemistry, along with University and University Studies requirements, are summarized here. The specific requirements for the teaching major and for the composite teaching major in physical science are also included.

Students are also urged to study these requirements and to visit with their advisor on a regular basis about progress toward the completion of their degrees or for any questions regarding complementary courses and career goals.

### General Requirements

**Admission Requirements.** First-year students admitted to USU in good standing qualify for admission to this major. Transfer students from other institutions need a 2.2 transfer GPA, and students transferring from other USU programs need a 2.0 total GPA for admission to this major in good standing.

Students interested in studying chemistry should take high school mathematics courses that will enable them to start calculus during their first semester at USU. High school coursework in chemistry and physics is also desirable. AP credit in chemistry may be counted toward the degree. For details, contact the departmental advising faculty.

No Chem prefix course may be applied toward graduation with any major in chemistry with an earned grade of less than C-. Except for Chem 4800 and 4990, no Chem prefix course may be taken on a *Pass/Fail* basis. No Chem prefix course may be repeated more than one time to improve the grade to a C- or better. A student dropped from the chemistry program for failure to meet this standard may appeal to the departmental Curriculum Committee for readmission.

### Chemistry Core Curriculum

In addition to the University Studies requirements for graduation, chemistry majors take a series of core courses spread across a traditional four-year period. The completion of the chemistry core also covers the College of Science requirements for graduation.

**First Year:** Chem 1210, 1220, 1230, 1240; Math 1210, 1220.

**Second Year:** Chem 2310, 2320, 2330, 2340, 3510, 3520, 3600, 3610; Phyx 2210, 2220; Math 2210.

**Third Year:** Chem 3060, 3070, 3080, 3090, 5700; Math 2250 or Stat 3000 (optional for Chemistry Teaching Major).

**Fourth Year:** Chem 4990.

### Chemistry Requirements

**Professional Chemistry Emphasis (ACS Certified).** In addition to the chemistry core, Chem 5520, 5530, 5640, 5650; and 6 advanced electives, as approved by the department, are required.

**Biochemistry Emphasis (ACS Certified).** In addition to the chemistry core, Chem 5640, 5650, 5710, 5720; Biol 1210; and 6 advanced electives, as approved by the department, are required.

**Chemical Education Emphasis (ACS Certified).** In addition to the chemistry core, Chem 5520 and 5530, or Chem 5640 and 5650, or Chem 5710 and 5720; teaching licensure courses as specified by the Department of Secondary Education (35 cr.); and teaching minor from outside the Department of Chemistry and Biochemistry (12-16 cr.) are required.

**BS Degree with Honors.** This option can be met by completing any ACS certified program and by meeting the following requirements: Minimum GPA of 3.50 in chemistry courses; overall GPA of 3.30; 13 credits of honors work as follows: 3-6 credits of Chem 4800H (Research Problems), 3 credits chosen from Chem 2320H, 3070H, 5640H, or 5700H, 1 credit of Chem 4990H (Undergraduate Seminar), and 3-6 credits selected from Honors courses numbered 3000 or above in chemistry or related subjects, as appropriate. Three credits may be selected from chemistry courses numbered 6000 or above. Students must be admitted to Honors through the Honors Program Office.

**BS in Chemistry, Life Science Emphasis.** In addition to the chemistry core, Biol 1210; Biol 1220 or 2000; Biol 3200 or 3300; and Chem 5710, 5720 are required.

**BA in Chemistry:** In addition to the chemistry core, Chem 5520 or 5640; and two years of foreign language are required.

**Chemistry Teaching Major:** In addition to the chemistry core (minus the Math 2250 or Stat 3000 courses), Sci 4300, teacher licensure courses offered by Secondary Education (35 cr.), and a teaching minor from outside the Department of Chemistry and Biochemistry (12-16 cr) are required. An overall 2.75 GPA in a minimum of 60 semester credits of approved University coursework is required for admission into the Secondary Teacher Education Program (STEP). A minimum overall GPA of 2.75 is required for graduation. Specific for admission to this program, a student must have at least a 2.75 GPA in Chem 1210, 1220, 1230, and 1240.

**Composite Teaching Major in the Physical Sciences.** This degree is available through the Chemistry and Biochemistry or Physics departments. Students with a Composite Teaching Major in Physical Sciences should plan their programs carefully in order to meet the upper-division requirement for graduation. An overall 2.75 GPA in a minimum of 60 semester credits of approved University coursework is required for admission into the Secondary Teacher Education Program (STEP). A minimum overall GPA of 2.75 is required for graduation.

Specific for admission to this program, a student must have at least a 2.75 GPA in the following chemistry and physics courses: Chem 1210, 1220, 1230, 1240; Phyx 2110, 2120, or Phyx 2210, 2220 (preferred). *This program does not include many aspects of the Chemistry Core.*

**Required Courses:** Chem 1210, 1220, 1230, 1240; Chem 2300 or 2310; Chem 2330; Phyx 1000; Phyx 1030 or 3030; Phyx 2110

and 2120, or Phyx 2210 and 2220; Math 1210, 1220; Stat 3000; Sci 4300; Biol 1010; Geol 1150; Bmet 2000; and teacher licensure courses from Secondary Education (35 cr.). A teaching minor is optional for the Composite Teaching Major in the Physical Sciences.

**Chemistry Minor.** In addition to Chem 1210, 1220, 1230, and 1240, 10 additional credits in Chemistry prefix courses at the 2000 level or higher are required.

**Chemistry Teaching Minor.** In addition to Chem 1210, 1220, 1230, 1240, Chem 2300 or 2310, and Chem 2330, 3 additional credits selected from the following are required: Chem 2320 (if Chem 2310 has been previously selected), Chem 3060, *both* Chem 3510 and 3520, Chem 3600, Chem 3650, or Chem 3700.

### **Career Opportunities**

Chemistry degree holders work in a wide variety of professions, from physicians, lawyers, and professors to research/development, sales, or production in the chemical, oil, pharmaceutical, metals, electronic, and biochemical industries. Government at all levels employs chemists, including the federal Departments of Defense, Health and Human Services, Agriculture, and Interior. A graduate with a bachelor's degree often begins work in chemical analysis or sales or may assist senior chemists in research and development. A graduate with a teaching major or chemistry education emphasis may teach in public schools. A graduate degree is usually needed to direct research or teach at the university level. Degree holders from the Department of Chemistry and Biochemistry have had excellent success in obtaining support for graduate studies, often at very prestigious institutions, and in obtaining employment directly following graduation. For further information, students should contact their advisor.

## **Graduate Programs**

### **Admissions Requirements**

See the general admission requirements for the School of Graduate Studies (pages 72-73). All applicants should have a bachelor's degree or master's degree in chemistry or biochemistry from an accredited institution. Appropriate undergraduate preparation is expected; applicants not fully prepared may be admitted with the condition that appropriate undergraduate courses are taken as necessary.

Applications are especially encouraged during the spring semester for expected admission in the following fall semester. However, the Graduate Recruiting and Admissions Committee screens applications throughout the year. Detailed information about the graduate programs and faculty research activities can be found on the Internet at <http://www.chem.usu.edu>.

### **Degree Programs**

**Master of Science.** To earn an MS in chemistry or biochemistry, a student must meet the general requirements of the School of Graduate Studies (see pages 76-77), conduct research under the direction of a major professor and write a thesis acceptable to a supervisory committee (Plan A) or write a review-of-literature paper (Plan B), and pass an oral examination that is principally a defense of the thesis or the Plan B paper.

Qualified undergraduate chemistry majors at USU may apply in the third year for admission to the MS program. Students may be admitted to this MS program if they have a *B* average in chemistry, physics, and mathematics courses, and have completed the one-year sequences in general, organic, and physical chemistry (including labs), two courses in analytical or inorganic chemistry, two semesters of physics, math through Math 2210, and at least 15 credits of their University Studies requirements.

Students should consult with the chairman of the Graduate Recruiting and Admissions Committee to be certain of their eligibility for this program. The chairman will then submit an application to the department head and to the School of Graduate Studies for approval. Students must earn a satisfactory grade on the GRE exam before the completion of the MS degree. All requirements for the BS degree must be completed within two semesters of admission. The MS coursework cannot include coursework counted toward the BS degree.

**Doctor of Philosophy.** To earn the PhD in chemistry or biochemistry, a student must successfully complete a core curriculum of courses and other courses as approved by a supervisory committee. In addition, preliminary examinations (both oral and written) must be passed and research in a field of specialization must be conducted. The final requirement is the writing and defense of a dissertation before the student's supervisory committee.

**Biochemistry Course Requirements.** Every MS and PhD student in the biochemistry program must complete Chem 6730, 6740, 6750, and 6760. In addition, all students must register for at least 2 credits of Chem 6720 in the first semester of residence to participate in research training. Both MS and PhD students must complete a total of at least 15 credits in coursework, exclusive of seminar and research credit. The Program of Study is approved by the student's supervisory committee. A total of 30 credits is required for the MS degree, and a total of 90 credits is required for the PhD. Beginning students who already hold an MS degree need 60 credits to complete the PhD program.

**Chemistry Course Requirements.** Every MS and PhD student in the chemistry program must complete the courses required for their specialization: *Analytical*—Chem 7600, 7610; *Inorganic*—Chem 6500, 6510; *Organic*—Chem 6300, 7300, 7310; or *Physical Chemistry*—Chem 6000, 6010, 7020. Both MS and PhD students must complete a total of at least 15 credits in coursework, exclusive of seminar and research credit. The Program of Study is approved by the student's supervisory committee. A total of 30 credits is required for the MS degree and a total of 90 credits is required for the PhD. Beginning students who already hold an MS degree need 60 credits to complete the PhD program.

### **Financial Assistance**

The department offers financial support to students in the form of teaching assistantships, research assistantships, and fellowships. All applications for admission to the School of Graduate Studies constitute an application for financial assistance; it is not necessary to file a separate request. Teaching assistantships are the principal means of support for first-year students. Inquiries about current support levels should be directed to the department main office. The department is responsible for the first nine months of stipend and tuition, with the remaining summer stipend and tuition usually being paid from faculty research funds. Teaching assistants devote no more than 12 contact hours per week directing undergraduate laboratories, leading recitation sec-

tions, and assisting students with questions during the regular fall and spring semesters. Research assistantships, funded from individual faculty research grants, support students conducting research related to the grant projects. Although first-year students are not normally supported as research assistants, well-prepared students may be eligible for research support at the discretion of their major professor.

Fellowships are awarded by the University to outstanding students solely on the basis of merit. The department encourages students with strong academic records to apply for the University fellowships and national awards, and will provide assistance in obtaining and submitting the appropriate forms. Additionally, several graduate awards are given each year to honor exemplary performance in research and teaching.

The College of Science recently established the Willard L. Eccles Foundation Science Fellowship. The \$15,000 per year, three-year stipend is competitively awarded to highly qualified science applicants. Students applying to the graduate program will be considered for this fellowship, and will be sent the necessary information. Application deadline for this fellowship is March 1.

## Chemistry and Biochemistry Courses (Chem)

**Chem 1010 (BPS). Introduction to Chemistry.** For nonscience majors. Includes basic chemical concepts and a survey of the various branches of chemistry. Heavy emphasis on everyday applications to problems involving environmental pollution, radioactivity, energy sources, and human health. No prerequisites. (3 cr) (F,Sp) ©

**Chem 1110. General Chemistry I.** For nonscience majors. Progression made from the basic tenets of general chemistry to introduction to organic chemistry, with ascent in terms of practical importance and sophistication. Prerequisite: Math ACT score of at least 23, or Math 1050 or higher. (4 cr) (F,Sp)

**Chem 1120 (BPS). General Chemistry II.** Continuation of Chem 1110. Continued coverage of organic chemistry, along with introduction to biochemistry. Prerequisite: Chem 1110. (4 cr) (Sp)

**Chem 1130. General Chemistry Laboratory.** Laboratory course designed to accompany Chem 1110. Covers basic aspects of general chemistry. (1 cr) (Sp)

**Chem 1210. Principles of Chemistry I.** First of a two-semester sequence, covering fundamentals of chemistry. Designed for science and engineering students. Prerequisite: Math ACT score of at least 25, or Math 1050 or higher. High school chemistry recommended. (4 cr) (F,Sp)

**Chem 1220 (BPS). Principles of Chemistry II.** Continuation of Chem 1210. Prerequisite: Chem 1210. (4 cr) (F,Sp,Su)

**Chem 1230. Chemical Principles Laboratory I.** Laboratory course designed to be taken concurrently with Chem 1210. Experiments cover acids/bases, thermochemistry separations, molecular weights, gases, and spectroscopy. Prerequisite: Chem 1210 (may be taken concurrently). (1 cr) (F,Sp)

**Chem 1240. Chemical Principles Laboratory II.** Continuation of Chem 1230. Normally taken concurrently with Chem 1220. Experiments cover elementary kinetics, electrochemistry, gravimetric analysis, chromatography, and equilibria. Prerequisite: Chem 1230. (1 cr) (F,Sp)

**Chem 2300. Principles of Organic Chemistry.** Shape, bonding, nomenclature, stereochemistry, physical properties, and reactivity of organic molecules is covered for a range of molecules, beginning with simple alkanes and finishing with some of the more complex abiotic and biotic organic molecules known today. Prerequisite: Chem 1210. (3 cr) (F)

**Chem 2310. Organic Chemistry I.** First of a two-semester sequence, covering physical properties, nomenclature, mechanisms of reactions, and biological relevance of organic and bioorganic molecules. Prerequisite: Chem 1220. (4 cr) (F,Sp)

**Chem 2320. Organic Chemistry II.** Continuation of Chem 2310. Prerequisite: Chem 2310 or Chem 2300 and permission of instructor. (4 cr) (Sp)

**Chem 2330. Organic Chemistry Laboratory I.** Laboratory course designed to accompany Chem 2310. Covers basic aspects of experimental organic chemistry. Prerequisites: Chem 1210 and 1230. (1 cr) (F,Sp)

**Chem 2340. Organic Chemistry Laboratory II.** Continuation of Chem 2330. Prerequisite: Chem 2330. (1 cr) (Sp)

**Chem 3060 (QI). Physical Chemistry.** Chemical thermodynamics. Laws of thermodynamics. Changes of state. Chemical equilibrium. Introduction to quantum mechanics. Schrodinger equation. Exactly-soluble problems. Prerequisites: Chem 1220, Math 2210, Phys 2220. (3 cr) (F)

**Chem 3070 (QI). Physical Chemistry.** Chemical applications of quantum mechanics, periodic table, and chemical bonding. Spectroscopy. Statistical thermodynamics. Chemical kinetics. Rate laws. Reaction mechanisms. Theories of reaction rates. Prerequisite: Chem 3060. (3 cr) (Sp)

**Chem 3080 (CI). Physical Chemistry Laboratory I.** Experimental work to accompany Chem 3060. Corequisite: Chem 3060. (1 cr) (F)

**Chem 3090 (CI). Physical Chemistry Laboratory II.** Continuation of Chem 3080. Experimental work to accompany Chem 3070. Corequisite: Chem 3070. (1 cr) (Sp)

**Chem 3510. Intermediate Inorganic Chemistry.** Survey of basic structure, bonding, and reactivity across the periodic table. Prerequisite: Chem 1220. (2 cr) (Sp)

**Chem 3520. Inorganic Chemistry Laboratory.** Covers basic aspects of inorganic synthesis and compound characterization. Corequisite: Chem 3510. (1 cr) (Sp)

**Chem 3600 (QI). Quantitative Analysis.** Basic theory and laboratory practice in analytical chemistry, including introduction to multiple equilibria and chemical separation methods. Prerequisites: Chem 1230, 1240, Math 1050. (3 cr) (F)

**Chem 3610. Quantitative Analysis Laboratory.** One three-hour laboratory per week. Must be taken concurrently with Chem 3600. Prerequisites: Chem 1230, 1240, Math 1050. (1 cr) (F)

**Chem 3650 (DSC). Environmental Chemistry.** Survey of issues and chemical nature of environmental problems, including air, soil, and water pollution. Prerequisite: Chem 1010 or 1120 or 1220. (3 cr) (Sp)

**Chem 3700. Introductory Biochemistry.** Brief survey of the chemistry of biologically important compounds and their role in microbial, animal, and plant metabolism. Prerequisite: Chem 2300 or 2310. (3 cr) (Sp)

**Chem 3710. Introductory Biochemistry Laboratory.** Laboratory course designed to accompany Chem 3700. Corequisite: Chem 3700. (1 cr) (Sp)

**Chem 4250. Cooperative Experience.** Planned work outside the University. Specific experience must receive prior approval for credit to be earned. Consult advisor or department head for details. (1-2 cr) (F,Sp,Su) ©

**Chem 4800 (CI). Research Problems.** Directed undergraduate research. Departmental permission required. (1-2 cr) (F,Sp,Su) ®

**Chem 4990 (CI). Undergraduate Seminar.** Writing and speaking skills necessary for presenting scientific information. (1 cr) (F,Sp) ®

**Chem 5160. Methods in Biotechnology: Cell Culture.** Techniques and fundamental knowledge for culturing mammalian and insect cells. Students will learn maintenance, growing, genetic engineering of cells, cytotoxicity, hybridoma creation, cloning, etc. Extensive laboratory experience is provided. Also taught as ADVS 5160, Biol 5160, NFS 5160, and PSB 5160. (3 cr) (Sp)

**Chem 5240. Methods in Biotechnology: Protein Purification Techniques.** Reviews basic methods of protein purification, including scaled-up use of 100L fermenter, large-scale centrifugation, diafiltration, chromatography, and use of BioCAD. Prerequisite: Chem 3700. Also taught as ADVS 5240, Biol 5240, NFS 5240, and PSB 5240. (3 cr) (Sp)

**Chem 5260. Methods in Biotechnology: Molecular Cloning.** Laboratory-oriented course designed to teach molecular biology techniques such as DNA cloning, genetic probes, polymerase chain reaction, and DNA sequencing. Prerequisite: Chem 3700 or 5710; or Biol 3200; or permission of instructor. Also taught as ADVS 5260, Biol 5260, NFS 5260, and PSB 5260. (3 cr)

**Chem 5520. Advanced Inorganic Chemistry.** Advanced treatment of the structure/bonding/reactivity relationships across the periodic table. Prerequisites: Chem 3070, 3510. (2 cr) (F)

**Chem 5530. Advanced Synthesis Laboratory.** Laboratory course in advanced synthetic techniques, including vacuum lines, inert atmosphere, Schlenk manipulations, liquid ammonia solvent, and tube furnace reactions. Prerequisites: Chem 2340, 3070, 3520. (2 cr) (Sp)

**Chem 5640. Instrumental Analysis.** Theory and application of physicochemical methods of analysis. Chromatography. Selected electrochemical and optical methods. Prerequisites: Chem 3080, 3610. (3 cr) (Sp)

**Chem 5650. Instrumental Analysis Laboratory.** Laboratory course to accompany Chem 5640. Two three-hour labs per week. Prerequisites: Chem 3080, 3610. (2 cr) (Sp)

**Chem 5700. General Biochemistry I.** General biochemistry for science majors, including proteins, enzymes, catalysis, bioenergetics, and catabolic metabolism. Prerequisite: Chem 2320. (3 cr) (F)

**Chem 5710. General Biochemistry II.** Continuation of Chem 5700. General biochemistry for science majors, including anabolic metabolism, DNA, RNA, and protein synthesis. Prerequisite: Chem 5700. (3 cr) (Sp)

**Chem 5720. General Biochemistry Laboratory.** Prerequisite: Chem 5710 (may be taken concurrently). (1 cr) (Sp)

**Chem 6000. Advanced Physical Chemistry.** A first-year graduate course in physical chemistry. Prerequisites: Chem 3070, Math 2250. (3 cr) (F)

**Chem 6010. Quantum Chemistry.** Quantum mechanics applied to chemical problems. Theory of atoms and molecules. Prerequisites: Chem 3070, Math 2250. (3 cr) (Sp)

**Chem 6300. Advanced Modern Organic Chemistry.** Covers topics in molecular structure, reaction mechanisms of organic molecules, and physical organic chemistry. Prerequisites: Chem 2320, 3070. (3 cr) (F)

**Chem 6500. Reactivity and Mechanisms in Inorganic Chemistry.** Inorganic reactions and mechanisms relevant to areas of main group, transition metals, and bioinorganic and organometallic chemistry. Prerequisite: Chem 5520. (3 cr) (Sp)

**Chem 6510. Chemical Applications of Group Theory.** Introduction to symmetry point groups and theorems of group theory for application to structure, bonding, and spectroscopy. Some familiarity with linear algebra is recommended. Prerequisite: Chem 3070. (1 cr) (F)

**Chem 6600. Modern Chemical Analysis.** Methodology and statistical treatment of chemical data, experimental design, quality control, and chemical separations. Prerequisite: Chem 5640. (3 cr) (Sp)

**Chem 6720. Advanced Biochemistry Laboratory.** To obtain advanced laboratory skills, students complete specific laboratory experiments in research laboratories of departmental faculty members. (2 cr) (F,Sp) ®

**Chem 6730. Principles of Enzymology.** Mechanisms of enzyme action, emphasizing recent advances in enzymology, including theory and modern experimental approaches to elucidation of mechanism. Prerequisite: Chem 5700 or equivalent. (3 cr) (F)

**Chem 6740. Principles of Protein and Nucleic Acid Structure.** Fundamental elements of protein and nucleic acid structure and function. Recent advances in the area of protein and nucleic acid structure having direct implications to their function. Methods for macromolecular structure determination. Prerequisite: Chem 5700 or equivalent. (3 cr) (Sp)

**Chem 6750. Principles of Metabolic Regulation.** Integration and regulation of mammalian metabolism. Communication among cells and tissues, molecular mechanisms of signal transduction (including protein phosphorylation and proteolytic activation), activation of transcription factors, and regulation of gene expression. Prerequisite: Chem 5700 or equivalent. (3 cr) (Sp)

**Chem 6760. Principles of Bioenergetics.** Global biological energy cycles including carbon, nitrogen, and sulfur cycles; respiration; electron transfer; and energy transduction. Prerequisite: Chem 5700 or equivalent. (3 cr) (F)

**Chem 6910. Special Problems in Chemistry and Biochemistry.** Selected problems in chemistry and biochemistry. Registration permitted only with written permission from department head. (1-4 cr) (F,Sp,Su)

**Chem 6970. Thesis Research.** Research for MS degree. (1-10 cr) (F,Sp,Su) ®

**Chem 6990. Continuing Graduate Advisement.** (1-3 cr) (F,Sp,Su) ®

**Chem 7000. Chemical Kinetics.** Theory of reaction rates with application to current research. Prerequisite: Chem 6000. (3 cr) (F)

**Chem 7010. Chemical Thermodynamics.** Study of interconversion of heat, work, and other forms of energy. Prerequisite: Chem 3070. (3 cr) (F)

**Chem 7020. Statistical Mechanics.** Statistical mechanics with applications to research problems of current interest. Prerequisite: Chem 6010. (3 cr)

**Chem 7030. Special Topics in Physical Chemistry (Topic).** Covers special areas of current interest and activity in physical chemistry. Prerequisite: Chem 6000. (3 cr) (F,Sp) ®

**Chem 7300. Reactions and Synthesis in Modern Organic Chemistry.** Reactions of modern organic chemistry and their application to organic synthesis. Prerequisite: Chem 6300. (3 cr) (Sp)

**Chem 7310. Molecular Structure/Spectroscopy of Organic Compounds.** Modern methods of predicting and determining molecular structure of organic compounds using advanced computational and spectroscopic tools. Prerequisite: Chem 6300. (3 cr) (F)

**Chem 7330. Special Topics in Organic Chemistry (Topic).** Covers special areas of current interest and activity in organic chemistry. Prerequisite: Chem 6300. (3 cr) (F,Sp) ®

**Chem 7500. Coordination Chemistry.** Theory and spectroscopy of transition metal coordination complexes. Prerequisites: Chem 3070, 6500, 6510. (3 cr) (Sp)

**Chem 7510. Bioinorganic Chemistry.** Advanced systematic study of metallo-biochemical structure and function. Prerequisite: Chem 6500. (1-3 cr) (F)

**Chem 7530. Special Topics in Inorganic Chemistry (Topic).** Topics of current interest in inorganic chemistry. Prerequisite: Chem 6500. (3 cr) (Sp) ®

**Chem 7600. Analytical Spectroscopy.** Practical description of spectroscopy-based analysis, emphasizing instrumentation and methods. Prerequisites: Chem 5640, graduate standing, or instructor's permission. (3 cr) (Sp)

**Chem 7610. Chemical Separations.** Survey of theory and practice of modern chemical separations, including extractions, chromatography, distillation, and phase separations. Prerequisite: Chem 5640 or instructor's permission. (3 cr) (F)

**Chem 7620. Electrochemistry.** Survey of electrochemistry with emphasis on electrochemical analysis. Prerequisite: Chem 5640. (3 cr) (F)

**Chem 7640. Special Topics in Analytical Chemistry (Topic).** Topics may include electronics from the scientist's perspective, laser-based spectroscopy, mass spectrometry, and chemometrics. Prerequisite: Chem 6600. (1-3 cr) (F,Sp) ®

**Chem 7770. Special Topics in Biochemistry (Topic).** Topics of current interest in biochemistry. (2-3 cr) ®

**Chem 7800. Seminar.** Graduate seminar. (1 cr) (F,Sp,Su) ®

**Chem 7970. PhD Dissertation Research.** (1-12 cr) (F,Sp,Su) ®

**Chem 7990. Continuing Graduate Advisement.** (1-9 cr) (F,Sp,Su) ®

® Repeatable for credit. Check with major department for limitations on number of credits that can be counted for graduation.

© This course is also offered by correspondence through Continuing Education Independent and Distance Education.