

Chemistry & Biochemistry

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COLLEGE OF SCIENCE

Graduate Faculty:

Bausch, Mark J., Associate Professor, Ph.D., Northwestern University, 1982; 1987. Organic radical anion basicities, radical acidities, stability of organic cations.

Davis, Joe M., Professor, *Emeritus*, Ph.D., University of Utah, 1985; 1987.

Du, Zhihua, Assistant Professor, Ph.D., University of Texas-Austin, 1997; 2009. Structural biology, NMR and X-ray crystallography, synthetic biology, bioinformatics.

Gao, Yong, Associate Professor, Ph.D., University of Alberta, 1998; 2000. Bio-organic chemistry; medicinal chemistry; biomaterials.

Gagnon, Keith T., Assistant Professor, Ph.D., North Carolina State University, 2007; 2014. Biochemistry of nucleic acids, RNA and DNA-protein interactions in biology and disease.

Ge, Qingfeng, Professor, Ph.D., Tianjing University, 1991; 2003. Physical/Materials Chemistry, computational chemistry, surface science, kinetics and catalysis, biomaterials and biocatalysis.

Goodson, Boyd M., Professor, Ph.D., University of California, Berkeley, 1999; 2002. Structure and dynamics of molecules and proteins, optical/nuclear double resonance, NMR and MRI, quantum computation.

Hinckley, Conrad C., Professor, *Emeritus*, Ph.D., University of Texas, 1964; 1966.

Hou, Yuqing, Research Assistant Professor, Ph.D., Southern Illinois University Carbondale, 1997; 1998.

Kinsel, Gary R., Professor and *Chair*, Ph.D., University of Colorado Boulder, 1989; 2005. Analytical Chemistry, MALDI and ESI mass spectrometry, RF plasmopolymers, biomaterials, proteomics, microfluidics, surface analysis.

Kohli, Punit, Associate Professor, Ph.D., Michigan State University, 2000; 2004. Bionanoscience, transport through nanotubes, materials and surface chemistry.

Koropchak, John A., Professor, *Emeritus*, Ph.D., University of Georgia, 1980; 1984.

Koster, David F., Professor, *Emeritus*, Ph.D., Texas A&M University, 1965; 1967.

McCarroll, Matthew E., Professor, Ph.D., University of Idaho, 1998; 2000. Analytical, molecular spectroscopy, fluorescence sensors, chiral and molecular recognition, capillary electrophoresis.

Moran, Sean D., Assistant Professor, Ph.D., Columbia University, 2008; 2014. Biophysical chemistry, biomolecular dynamics, and ultrafast infrared spectroscopy.

Plunkett, Kyle, Assistant Professor, Ph.D., University of Illinois, 2005; 2010. Organic chemistry, polymers, organic electronic materials, surface chemistry.

Scott, Colleen, N., Assistant Professor, Ph.D., University of Pittsburgh, 2005; 2010. Organic synthesis – polymeric materials, silicon chemistry – sensors, materials, synthetic methodology.

Smith, Gerard V., Professor *Emeritus*, Ph.D., University of

Arkansas, 1959; 1966.

Suni, Ian I., Professor, Ph.D., Harvard University, 1992; 2013. Electrochemistry, including applications to biosensing, thin film growth, nonomaterials, and corrosion.

Tolley, Luke T., Associate Professor, Ph.D., University of North Carolina, 2001; 2003. Analytical Chemistry, chromatography, capillary electrophoresis, mass spectroscopy, intercellular signaling biomarkers.

Trimble, Russell F., Professor, *Emeritus*, Ph.D., Massachusetts Institute of Technology, 1952; 1954.

Tyrrell, James, Professor, *Emeritus*, Ph.D., University of Glasgow, 1963; 1967.

Wang, Lichang, Professor, Ph.D., University of Copenhagen, 1993; 2001. Physical, theoretical/ computational chemistry, transition metal nanoparticles, organic photoelectronic materials, polymers, and biomolecules.

Programs leading to the Doctor of Philosophy and Master of Science degrees may be undertaken in the general areas of analytical, biochemistry, inorganic, materials, organic, and physical chemistry. The doctoral degree in chemistry is a research degree. To be awarded this degree, the student must demonstrate, to the satisfaction of the graduate committee, the ability to conduct original and independent research within some area of chemistry and must make an original contribution to the science. The master's degree also requires a research project, but with less emphasis on originality and independence.

Admission. Each student must have a baccalaureate degree in one of the sciences, mathematics, or engineering to be considered for admission to an advanced degree program.

An undergraduate major in chemistry, with the following courses, is desirable:

1. One year of organic chemistry (lecture and laboratory).
2. One year of calculus-based physical chemistry (lecture and laboratory).
3. One year of analytical chemistry including instrumental analysis.

Students with deficiencies in any area may be admitted, but such deficiencies may restrict the research areas available to the student and lead to requirements for additional courses during graduate study.

Prospective students are encouraged to contact faculty in areas of the students' research interest.

Applicants are strongly encouraged to submit Graduate Record Examination (GRE) general and chemistry test scores.

Foreign students whose native language is not English will be required to obtain at least 550 paper score, 220 computer score, on the Test for English as a Foreign Language (TOEFL).

This program requires a nonrefundable \$65.00 application fee that must be submitted with the application for Admissions to Graduate Study in Chemistry and Biochemistry. Applicants must pay this fee by credit card.

Placement Examinations. During the week before the beginning of classes, each admitted student is given written examinations (ACS standard or equivalent examination) in the five divisions of chemistry: analytical, inorganic, organic, physical, and

biochemistry. Every student is required to take at least three exams. The results of these examinations are used to advise the student regarding any deficiencies to be corrected, and to place the student in appropriate courses as determined by a Graduate Student Advisory Committee. Therefore, we strongly encourage and expect all beginning students to review the appropriate undergraduate material before taking these examinations. Failure to pass the exams will generally require that the student take some remedial coursework.

Introduction to Research Techniques. All graduate students must register for CHEM 592, Introduction to Research, during the first fall semester in residence.

Minimum Registration. All students admitted to the department will register for a minimum of 9 credit hours every semester in residence except during the first semester, summer sessions, and while registered for CHEM 601 only. In the first semester, the students must register for a minimum of 6 credit-hours, and in every summer session, a minimum of 3 credit-hours. Registration for less than this requirement is not considered satisfactory progress toward a degree.

Formal Course Work Requirement. Each student must complete the courses specified by the student's graduate committee in the program of study.

Each student must complete the courses specified by the student's graduate committee in the program of the study. Generally, these will include the courses specified by the student's major division. The minimum course requirement for students in the masters and doctoral programs includes at least 21 credit hours of 500-level lecture-style courses and follows a "2+2+3" format, in which all students must take for credit at least two courses (six semester hours) within the student's major field and at least two courses (six semester hours) from outside the major field. In addition, students must take three lecture-style courses at the 500-level, which must be approved by the Student's Graduate Committee. These three courses may be within the student's major division or may be from outside the major field or outside the Department. Select 400-level lecture-style courses offered by the Chemistry Department (see Departmental Requirements and Regulations) are eligible, including CHEM 451A, CHEM 451B, CHEM 456, CHEM 468, and CHEM 479. Eligible courses taken while in the master's program in the chemistry department at SIU may be applied to these departmental courses requirements.

For a student working in a cross-divisional area, the committee will design an appropriate program of study in consultation with the Graduate Advisor and the faculty of the divisions involved. Students must receive credit for graded presentations recorded as CHEM 593. Masters and doctoral students are required to receive credit for CHEM 593A, which is a literature presentation that is organized through the students divisional journal club. In addition, doctoral students must receive credit for CHEM 593B and CHEM 593C, which are received for graded presentations associated with the presentation of an independent research proposal and a presentation of the students dissertation research, respectively.

All students must take 1 hour of CHEM 597, Professional Training, and one hour of CHEM 595, Journal Club, each

semester in residence.

Research Director and Graduate Committee Selection. Each student must select a research director and graduate committee preferably during the first semester, but no later than the end of the second semester in residence. The student must obtain a selection form provided by the graduate adviser and must interview at least 4 faculty members before selecting a research director and graduate committee. For a master's candidate, the committee shall consist of the research director (chair), at least 1 member of the major division other than the research director, and at least 1 member outside the major division. For a Ph.D. candidate, the committee is identical except that at least 1 member outside the department is included. The chair of the Department of Chemistry and Biochemistry, if not otherwise appointed, is an exofficio member of every graduate committee. A division may increase this requirement.

Graduate Committee Functions. The functions of the graduate committee are listed below.

1. To plan and approve the student's program of study.
2. To review the student's progress in courses and suggest and approve changes in the program of study.
3. To evaluate the student's progress in research and to make appropriate recommendations.
4. To determine whether a student may continue toward a degree. If continuation is denied, the committee must notify in writing the department chair of the reasons for this denial.
5. To read and evaluate the student's thesis or dissertation.
6. To conduct required oral examinations.

As soon as possible after being appointed, the committee will meet to plan the student's program. At this time the progress and program form is completed and filed with the graduate adviser. The committee may require preparation of a master's thesis even if directly pursuing a Ph.D. degree has been previously approved by the faculty.

Research Tools. The department requires no specific re-search tools. A student's graduate committee, taking into account the student's background and the needs of the research area, may require that the student acquire one or more research tools (e.g., foreign language, computer programming, statistics, etc.). It is the students' responsibility to see that any research tool requirement is completed before scheduling the preliminary oral examination.

Assistantship Support. Continuation of assistantship support is contingent upon the student making satisfactory progress toward a degree. In addition, continuation of teaching assistantship support depends upon satisfactory performance of assigned duties. The Graduate School has established time limits for financial support.

First Year Evaluation. The faculty, meeting as a committee of the whole, will review the progress of all graduate students at the end of their first year in residence. For students in the doctoral program the faculty can:

1. recommend continuation in the doctoral program.
2. recommend transfer to a terminal master's degree program.

3. request that the Graduate School terminate the student from the program (giving cause).

For students in the master's program the faculty can:

1. recommend petitioning the Graduate School to allow entry to the doctoral program (accelerated entry option). Such petition can be made any time after one semester in residence.
2. recommend continuation in the master's program with the option to petition the Graduate School to grant a master's degree equivalency. When granted, this allows the student to apply for entrance to the doctoral program without writing and defending a thesis.
3. recommend continuation in the master's program with option to petition to enter the doctoral program after completion of a master's thesis.
4. recommend continuation in a terminal master's program.
5. request that the Graduate School terminate the student from the program (giving cause).

Preliminary Examination for the Ph.D. Degree. Each student in the doctoral program must pass a preliminary examination before being advanced to candidacy. The first portion of the preliminary examination is given in the form of cumulative exams with 10 examinations scheduled each calendar year. The student must pass 4 examinations in no more than 10 consecutive trials. Students must begin cumulative examinations at the start of their second calendar year or immediately on admission to the doctoral program if one calendar year has already been completed in the master's program. After the student completes the cumulative examinations, the preparation and defense of an original research proposal will serve as the oral portion of the preliminary examination.

Research. A research project is required of all graduate students. A student in the doctoral program must earn at least 32 credit hours in research and dissertation (CHEM 598 and 600). A minimum of 24 hours must be dissertation credit (CHEM 600). The results of the research must be presented in the form of a dissertation acceptable to both the student's committee and to the Graduate School.

Dissertation. After being admitted to candidacy, the student must register for 24 semester hours of CHEM 600 and complete a dissertation acceptable to both the student's Graduate Committee and to the Graduate School before graduation. Students who have registered for the 24 semester hours of dissertation credit and have not completed the doctoral dissertation are subject to the continuing extended enrollment requirement described in the next section.

Extended Registration. A student who has completed all doctoral degree requirements with the exception of writing a dissertation, and who is in the process of writing a dissertation, must register for Chemistry 601 (1 to 12 credit hours per semester) until the dissertation is completed and defended.

Final Oral Examination. A student in the doctoral program must schedule and pass a final oral examination (defense of dissertation). The student will present a departmental seminar for credit (Chemistry 593C) based of the results of the research.

After questions from the general audience, the student's graduate committee will conduct an oral examination of the student. The grade for Chemistry 593C is based of the seminar presentation and is independent of the oral examination. Copies of the dissertation must be presented to members of the student's graduate committee at least one week before the seminar and the examination.

Courses (CHEM)

All laboratory courses in chemistry and biochemistry may require the student to purchase either special notebooks or workbooks. All students enrolled in a chemistry class that includes a laboratory session will be assessed a breakage charge for all glassware broken. This policy will apply to undergraduate and graduate students

411-3 Intermediate Inorganic Chemistry. Fundamentals of inorganic chemistry, covering bonding and structure, coordination compounds and the chemistry of some familiar and less familiar elements. Three lectures per week. Prerequisite: CHEM 360. Offered spring semester only.

431-3 Environmental Chemistry. Chemical principles applied to the environment and environmental problems. Chemical kinetics, thermodynamic and equilibrium concepts as they relate to the atmosphere, water and soil will be discussed to include current problems of pollutants, pollutant evaluation and pollutant remediation. Discussion of methods for the chemical analysis of environmental samples will also be included. Prerequisite: C or better in 330 and 340.

434-2 to 4 Instrumental Analytical Chemistry. Theory and practice of instrumental measurements, including emission and absorption spectroscopic, capillary electrophoretic and chromatographic methods. Two lectures and two three-hour laboratories per week for four credits. Enrollment for two credit hours is restricted to graduate students in the Department of Chemistry and Biochemistry who are advised to take instrumental analysis. Prerequisite: C or better in 330. Offered fall semester only. Laboratory fee: \$48.

439-3 Forensic Chemistry. A one semester course in the analysis of forensics samples. Topics include sample collection and preservation, chain of custody, data validation and reports, and analytical methods which may include (as time permits) chromatography, mass spectroscopy, fluorescence and absorbance spectroscopy, fingerprint identification, and scanning electron and light microscopy. One lecture and one six-hour laboratory meeting per week. Enrollment is limited with preference given to students with high academic standings. Prerequisite: C or better in 330 and 434. Offered spring semester only. Laboratory fee: \$48.

442-3 Organic Chemistry II. This is a continuation of 340 emphasizing topics that were not covered in the first semester. Topics will include the chemistry of aromatic compounds, dienes and other carbon-carbon bond forming reactions. Advanced topics such as polymers and biomolecules may also be covered. Three lectures per week. Prerequisite: C or better in 340, 341; concurrent enrollment in 343 is recommended. Offered spring semester only.

443-2 Organic Chemistry Laboratory II. A second organic laboratory course based upon a synthetic approach. Students

will learn modern synthetic organic chemistry techniques including modern spectroscopic techniques. One one-hour lecture and one four-hour laboratory per week. Prerequisite: *C* or better in CHEM 340, 341, 442 or concurrent enrollment in 442. Offered spring semester only. Lab fee: \$48.

444-3 Intermediate Organic Chemistry. A transitional course between introductory and graduate level chemistry. The chemistry of carbon compounds based upon a mechanistic approach will be discussed. Three lectures per week. Prerequisite: *C* or better in 340 and 442. Offered fall semester only.

451A- Biochemistry. (Same as Biochemistry 451A and Molecular Biology, Microbiology and Biochemistry 451A) First half of the 451 A,B two semester course. Must be taken in A,B sequence. Three lectures per week. Introduction to biomolecules, biochemical techniques, expression of genetic information, basic thermodynamics, ligand binding, aqueous solutions, protein structure, spectroscopy. Prerequisites: CHEM 340 and CHEM 342 or 442, or equivalents.

451B-3 Biochemistry. (Same as Molecular Biology, Microbiology and Biochemistry 451B and Biochemistry 451B) Second half of 451A,B two semester course. Must be taken in A, B sequence. Basic kinetics, enzyme kinetics, enzyme inhibitors, regulation of enzymes, oxidation-reduction, high energy bonds, transport across membranes, intermediary metabolism, hormonal control of metabolism. Prerequisites: MBMB 451A or BCHM 451A or CHEM 451A or equivalent.

456-3 Biophysical Chemistry. (Same as Biochemistry 456 and Molecular Biology, Microbiology and Biochemistry 456) A one-semester course in Biophysical Chemistry intended for biochemists and molecular biologists. Emphasis will be on solution thermodynamics, kinetics and spectroscopy applied to biological systems. Prerequisite: CHEM 340 and CHEM 342 or 442, MATH 141 or 150, MBMB 451A or BCHM 451A or CHEM 451A or equivalents.

460-3 Quantum Mechanics and Spectroscopy. An introduction to quantum mechanics and spectroscopy. Prerequisite: Mathematics 250; *C* or better in 360. MATH 221 or 305 is recommended as prerequisite or concurrent enrollment. Offered spring semester only.

468-3 Application of Symmetry to Chemistry. The concepts of symmetry elements, groups and character tables will be taught. Symmetry will be applied to molecules in order to simplify and characterize their wave functions and vibrational frequencies. Prerequisite: *C* or better in 460. Offered spring semester in odd years only.

479-3 Principles of Materials Chemistry. Introduction to fundamental concepts of materials chemistry. Synthesis, characterization, processing and applications of different materials including solids, polymers, ceramics and molecularly designed materials. Prerequisite: 360, 411 or concurrent enrollment. Offered fall semester in odd years only.

489-1 to 3 Special Topics in Chemistry. Special approval needed from the chair.

506-3 Chemistry Topics for Teachers. This graduate-level chemistry course covers topics, methods and activities that target the needs of elementary and middle school science teachers. The course consists of a combination of lectures and laboratory experiments. The specific subjects covered during

the course change, depending on the needs of the current students. This course may only be taken as part of an approved major. Special approval needed from the instructor.

511-6 (3,3) Advanced Inorganic Chemistry. (a) Principles of group theory and their application to molecular structure, ligand field theory and its application and magnetic properties of matter. **(b)** Energetics, kinetics and mechanisms of inorganic systems. Prerequisite: one year of physical chemistry, CHEM 411.

519-3 Advanced Topics in Inorganic Chemistry. Metal ions in biological processes and other selected topics to be announced by the department. Maximum credit nine semester hours. Special approval needed from the instructor.

531-3 Introduction to Analytical Separations. An introduction to the basic principles underlying separation science, with emphasis on all major chromatographies, gel and capillary electrophoresis, isoelectric focusing, field-flow fractionation, rate and isopycnic sedimentation, filtration, reverse osmosis and related methods. Prerequisite: MATH 250.

532-3 Analytical Chemistry Instrumentation. Introduction to analog and digital electronics and the computer control of system components. The course will focus on chemical instrumental and the use of filters, amplifiers and digital signal processing to improve sensitivity and detection limits. Two lectures and one three-hour laboratory per week. Prerequisite: CHEM 434.

533-3 Analytical Spectroscopy. Fundamental and experimental aspects of electronic and vibrational spectrometry, with a particular emphasis on the spectroscopic analysis of atomic and molecular species. Various sources of electromagnetic radiation, detectors, optical components and the optimization of experimental methods are covered in detail. Common spectroscopic techniques are covered in detail and a portion of the course covers newly emerging techniques and developments. Prerequisite: CHEM 434.

534-3 Electrochemistry. Fundamentals and applications of electrochemical methods, with emphasis on the thermodynamics and kinetics of electron transfer, electrode double-layer structures, as well as varied voltammetric techniques.

535-3 Advanced Analytical Chemistry. Course surveys various statistical, data-manipulative, and numerical methods as applied to analytical chemistry, including probability distributions, methods of maximum likelihood, linear and nonlinear least squares, correlation coefficients, chi-square, *F* and *T* distributions, Pearson statistics, analysis of variance, convolution, deconvolution, cross-correlation, autocorrelation, data acquisition, Nyquist theorem, aliasing, digitization errors, digital filtering, Monte Carlo methods, and finite-difference equations. Prerequisite: 434.

536-3 Principles of Mass Spectrometry. This course is an introduction to mass spectrometry with a focus on pharmaceutical and biological applications. Topics that will be covered include instrument design, ionization techniques, tandem mass spectrometry, chromatography/mass spectrometry and mass spectral interpretation. Prerequisite: 434.

537-3 Fluorescence Spectroscopy. Fundamental and experimental aspects of analytical methods based on the various phenomena of luminescence. General principles of luminescence are covered in detail, as well as analytical techniques based on fluorescence quenching, energy transfer,

polarization, and time resolved methods. Aspects of source of electromagnetic radiation, detectors, and electronic/optical components are discussed specifically as they pertain to fluorescence spectroscopy. Newly emerging fluorescence based techniques are also discussed. Prerequisite: 434 and 533 (or consent of the instructor).

538-3 Nanoscale Probing and Imaging. This course covers basic principles of scanning probe microscopy and spectroscopy including STM, AFM, ACM and NSOM, and the broad applications in nanoscale probing and imaging. Topics include surface characterization and manipulation, nanolithography, nanomaterials, self-assembly, molecular electronics, optoelectronics, nanoscale electron transfer, single-molecular spectroscopy, protein structures, enzyme dynamics, and living cell imaging. Prerequisite: undergraduate physical and analytical chemistry.

539-3 Advanced Topics in Analytical Chemistry. Selected topics of interest to practicing analytical chemists such as microanalytical chemistry, functional-group chemical determinations, absorption spectroscopy and electro-analytical chemistry. Maximum credit nine semester hours. Prerequisite: CHEM 434 with a minimum grade of C.

541-3 Organic Structure and Reactivity. Structure and reactivity of organic compounds: steric, electronic, kinetic and thermodynamic aspects and their relation to reactive intermediates.

542-3 Mechanistic Organic Chemistry. Reaction mechanisms in organic chemistry. Electrocyclic and sigmatropic reactions, cycloadditions, free radicals, photochemistry and organometallic catalysis. Spectroscopic methods.

543-3 Synthetic Organic Chemistry. Organic synthesis: classical and modern methods.

549-3 Advanced Topics in Organic Chemistry. Specialized topics in organic chemistry. The topic to be covered is announced by the department. Maximum credit nine semester hours. Prerequisite: CHEM 542.

552-3 Biomolecular Structure and Function. This course will cover the structural basis of biomolecules with an emphasis on the chemical and physical aspects involved in the architecture of proteins and nucleic acids. The study of the physical properties of biomolecular interactions and assembly of biomolecules into macromolecular complexes will be covered. Interpretation of data from atomic resolution techniques will be discussed. Prerequisites: 350 or 451A/B, or equivalent.

559-3 Advanced Topics in Biological Chemistry. Specialized topics in biological chemistry. The topic to be covered is announced by the department. Maximum credit nine semester hours. Prerequisite: C or better in CHEM 350 or CHEM 451A,B or equivalent.

560-3 Introduction to Quantum Chemistry. Basic principles and applications of quantum mechanics to chemistry. Topics include operator and vector algebra, classical mechanics, angular momentum, approximate methods, hydrogen-like atoms and molecular electronic structure. Three lectures per week. Prerequisite: one year of under-graduate physical chemistry.

561-3 Molecular Orbital Theory. An introduction to molecular orbital theory. Applications and limitations of various methods. Three lectures per week. Prerequisite: one year of undergraduate

physical chemistry including quantum mechanics.

562-3 Advanced Molecular Spectroscopy. Theory of rotational and vibrational spectroscopy, electronic spectroscopy of molecules. Three lectures per week. Prerequisite: 468 or consent of instructor.

563-3 Computational Chemical and Materials Sciences. An introduction to commercial molecular modeling soft-wares and to performing designed research projects related to chemical and materials sciences. Three lectures per week. Prerequisite: CHEM 360 and CHEM 460 (1 year of undergraduate Physical Chemistry) or consent of instructor.

564-3 Statistical Thermodynamics. Principles of statistical mechanics and applications to equilibrium and nonequilibrium systems. Topics include ideal gases, monatomic crystals, lattice statistics, the cluster method, correlation functions, Brownian motion, the Boltzmann equation and the Kubo-Green technique. Three lectures per week.

569-3 Advanced Topics in Physical Chemistry. Topic to be announced by the department. Maximum credit nine semester hours. Special approval needed from the instructor.

575-3 Methods of Materials Characterization. An introduction to the structural, morphological, spectroscopic, and thermal characterization techniques commonly used in materials chemistry. Special approval needed from the instructor.

579-3 Topics in Advanced Materials. Design and applications of advanced materials. Special topics will focus on contemporary research areas of interest as determined by the instructor. Special approval needed from the instructor.

592-1 Introduction to Research. Introduction to the techniques and methods of chemical research including good laboratory practice, research ethics, record keeping, publication, patents and currently active research in this department. Graded *S/U* only.

593A,B,C (1,1,1) Graded Seminar. Seminar presentations on advanced topics given in partial fulfillment of the requirements for the MS and PhD degrees in Chemistry. (a) Literature Seminar, (b) Independent Proposal Presentation, (c) Research Seminar.

594-2 to 3 Special Readings in Chemistry. Assigned library work in any of these fields of chemistry with individual instruction by a staff member. (a) Analytical, (b) biochemistry, (c) Inorganic, (d) Organic, (e) Physical. Maximum credit three hours.

595-1 Advanced Seminar in Chemistry. Advanced level talks presented by graduate students. (a) Analytical (b) biochemistry (c) inorganic, (d) organic, and (e) physical chemistry.

596-1 to 6 (1 to 3 per semester) Master's Degree Research. Graded research for Master's Degree only. Maximum 6 credit hours. Prerequisite: Completion of at least 9 hours of graded graduate course work in the program. Restricted to admission to Master's program in Chemistry and Biochemistry. Special approval needed from student's graduate advisory committee.

597-1 to 15 Professional Training. Experience in teaching of chemistry, instrument operation and special research projects. One hour required each semester in residence. Graded *S/U* only. Restricted to graduate standing.

598-1 to 50 (1 to 12 per semester) Research. Maximum credit 50 hours, except by permission of the student's graduate advisory committee. Graded *S/U* only. Special approval needed

from the chair.

599-1 to 6 Thesis. Maximum credit six hours. Special approval needed from the chair.

600-1 to 30 (1 to 12 per semester) Dissertation—Doctoral. Requirement for Ph.D. degree, 24 hours. Maximum credit 30 hours, except by permission of the student's graduate advisory committee. Prerequisite: CHEM 598.

601-1 per semester Continuing Enrollment. For those graduate students who have not finished their degree programs and who are in the process of working on their dissertation, thesis, or research paper. The student must have completed a minimum of 24 hours of dissertation research, or the minimum thesis, or research hours before being eligible to register for this course. Concurrent enrollment in any other course is not permitted. Graded *S/U* or *DEF* only.