# Chemistry

College of Science and Mathematics

**Department of Chemistry**
Ronald L. Marhenke, *Chair*
Rosalina Messer, *Administrative Support Coordinator*
Science Building, Room 380
559.278.2103
http://www.csufresno.edu/Chemistry

**B.A. in Chemistry**

**B.A. in Natural Sciences Teaching Credential**

**B.S. in Chemistry**

**M.S. in Chemistry**

**Minor in Chemistry**

**Biotechnology Certificate**


## Chemistry

The Chemistry Department provides: (1) undergraduate training in chemistry for students planning professional careers in chemistry, biochemistry and allied professions, and for those contemplating graduate work for advanced degrees; (2) undergraduate training in chemistry for those planning careers in professions such as medicine, chiropractic, dentistry, pharmacy, etc.; (3) participation in the preparation of teachers of chemistry and the other physical sciences in the teaching credential programs; (4) teaching of the basic chemical sciences required by students majoring in related fields such as physics, biology, nursing, engineering, geology, agriculture, home economics, and criminology; (5) stimulation of interest in and understanding of the achievements and contributions of chemistry to our civilization for non-science students, as a part of General Education; and (6) graduate instruction in chemistry for the Master of Science degree for students who intend to enter the chemical industry, pursue further advanced study, or who wish to improve their qualifications as teachers in secondary schools and community colleges.

The Bachelor of Science degree program in Chemistry is accredited by the American Chemical Society. Students who satisfactorily complete the program are recommended by the department for certification as graduate chemists by the American Chemical Society. Students completing the Bachelor of Arts degree may be recommended for certification by completing additional requirements of the American Chemical Society.

## Faculty

Sixteen Ph.D. members are in the Department of Chemistry. Our faculty provide excellent research opportunities in analytical, biochemistry, inorganic, organic, and physical chemistry. The broad interests within the faculty have resulted in interdisciplinary research projects in collaboration with scientists and professors in other science areas: agricultural chemistry, biotechnology, clinical chemistry, forensics chemistry, chemical physics, enology, nutritional science, and molecular biology. Research projects have involved local facilities such as the California State Crime Laboratory, University Medical Center, UCSF Fresno Medical Education Program, USDA Research Station, U.S. Veteran's Administration Hospital, U.S. Forest Laboratory, and Valley Children's Hospital.

## Facilities

All upper-division and graduate chemistry laboratories and support areas are housed in our science building. Eight four-station graduate laboratories are well equipped, with access to modern instrumentation. Instrumentation in the department includes: Varian EM 360 and Gemini 200 FT NMR spectrometers, GC-MS, atomic absorption spectrometers, Fourier Transform IR (FTIR), liquid scintillation counter, Lambda 6, Shimadzu, HP Diode-Array, spectrophotometers, spectrofluorometer, radiation equipment, liquid chromatographs, high speed refrigerated centrifuges, gas chromatographs, and Unix workstations for advanced computational chemistry. The university library includes many journal subscriptions in chemistry plus numerous texts and related books.

## Career Opportunities

Because of the increasing technological nature of our society, chemistry graduates will find an impressive array of options and exciting opportunities in a wide range of fields. A chemistry degree can provide preparation for a career as a professional chemist in areas such as basic research, environmental protection, instrumentation, new product and process development, and education. There is an increasing need for technical expertise in expanding fields such as agricultural chemistry, biotechnology, forensic science, clinical chemistry, food science, occupational safety, and environmental monitoring. Careers for chemists in the academics include university teaching and science teaching in the secondary school — an area that will expand greatly in the future. In addition there is a need for technically trained people in nontraditional areas such as marketing and sales, scientific information, patent law, and health and safety. The baccalaureate degree can also provide a strong foundation for studies at medical, dental, veterinary, and pharmacy schools. Students with chemistry degrees have been notably successful in these areas.

## Faculty

Ronald L. Marhenke, *Chair*
Kin C. Ng,
*Graduate Coordinator*

Saeed Attar
Sulekha Coticone
David L. Frank
Joseph R. Gandler
Barry H. Gump
Alam S. Hasson
Barbara J. Mayer
Howard K. Ono
Stephen A. Rodemeyer
Jose Sy
Joe D. Toney
Jarrad R. Wagner
Kin-Ping Wong
David L. Zellmer
Stanley M. Ziegler

## Undergraduate Programs

*Chemistry Majors*: The Bachelor of Arts degree with a major in chemistry consists of a total of 120 units including 38-39 units of chemistry. The Bachelor of Science degree with a major in chemistry consists of a total of 120 units including a minimum of 46 units in chemistry.

*High School Preparation*: The high school preparation for majors in the Department of Chemistry should include: algebra (2 years), plane and solid geometry, trigonometry, chemistry, and physics.

Prospective students may elect to take the general chemistry placement test at college entrance. A satisfactory score in this test will permit the student to start the chemistry course sequence with CHEM 1B.

## Bachelor of Arts Degree Requirements

The Bachelor of Arts in Chemistry is intended primarily for those students who plan to take extensive coursework in other areas in addition to chemistry. This degree is suitable for prehealth professional students (premedical, predental, etc.), secondary school teaching credential students, and biochemistry students oriented toward biotechnology and the health professions. This degree is *NOT* intended for students who anticipate a career in chemistry, or who expect to continue their education in pursuit of graduate degrees.

*Note*: Chemistry majors may not take courses listed in category A or B for *CR/NC* grades.

| | *Units* |
|---|---|
| **A. The B.A. Chemistry Major requirements** | **38-39** |
| *Core Program* | |
| CHEM 1A, 1B, 102, 108, 128A, 128B, 129A, 155 | (30) |
| *Emphasis* | |
| CHEM 156 | (3) |
| Elect two courses from CHEM 129B, 142, 153, 241A, 241B | (5-6) |
| **B. Additional requirements** | **32-39** |
| BIOSC 1A, 1B | (9) |
| Elect two courses from BIOSC 140A, BIOSC 140B, MICRO 140 or other approved courses | (7) |
| MATH 75, 76 (MATH 77 strongly recommended) | (8) |
| PHYS 2A, 2B (or PHYS 4A, 4AL, 4B, 4BL, 4C strongly recommended) | (8-11) |
| **C. Remaining General Education requirements** | **42*** |
| **D. Electives and remaining degree requirements** | **0-8** |
| (See *Degree Requirements*); may be used toward a double major or minor. | |
| **Total** | **120** |

*Of the 51 required General Education units, 9 units will be satisfied by the following courses in the major and additional requirements: 3 units of CHEM 1A or PHYS 2A in G.E. Breadth B1; 3 units of BIOSC 1A in G.E. Breadth B2; and 3 units MATH 75 in G.E. Foundation B4. Consult the department chair or faculty adviser for additional details.

The following is an example of a four-year program for the B.A. in Chemistry.

| First Semester — Fall | *Units* |
|---|---|
| CHEM 1A | 5 |
| MATH 75 | 4 |
| ENGL 1 | 3 |
| General Education | 3 |
| | 15 |

| Second Semester — Spring | |
|---|---|
| CHEM 1B | 5 |
| MATH 76 | 4 |
| PHYS 2A or 4A, 4AL | 4 |
| General Education | 3 |
| | 16 |

| Third Semester — Fall | |
|---|---|
| CHEM 128A | 3 |
| CHEM 129A | 2 |
| PHYS 2B or 4B, 4BL | 4 |
| BIOSC 1A | 4 |
| General Education | 3 |
| | 16 |

| Fourth Semester — Spring | |
|---|---|
| CHEM 128B | 3 |
| CHEM 102 | 5 |
| BIOSC 1B | 5 |
| Electives or General Education | 3 |
| | 16 |

| Fifth Semester — Fall* | |
|---|---|
| **CHEM 108 | 4 |
| **CHEM 155 | 3 |
| BIOSC 140A | 4 |
| Electives or General Education | 3 |
| | 14 |

| Sixth Semester — Spring | |
|---|---|
| ***CHEM 156 | 3 |
| BIOSC 140B or MICRO 140 | 4 |
| Electives or General Education | 6 |
| | 13 |

| Seventh Semester — Fall | |
|---|---|
| Electives or General Education | 15 |

| Eighth Semester — Spring | |
|---|---|
| Electives or General Education | 15 |
| **Total** | **120** |

*It is important to fulfill the upper-division writing skills requirement by exam or *W* class during the junior year.
**Offered fall semester only.
***Offered spring semester only.

## Bachelor of Science Degree Requirements

The Bachelor of Science in Chemistry is intended for students who plan a career in chemistry. The B.S. is accredited by the American Chemical Society. Students who satisfactorily complete this program are recommended by the department for certification as graduate chemists by the American Chemical Society. The B.S. prepares students to enter the job market or for graduate study leading to an advanced degree, such as a Master of Science or Doctor of Philosophy.

*Note:* Chemistry majors may not take courses listed in category A or B for *CR/NC* grades.

| | *Units* |
|---|---|
| **A. The B.S. Chemistry Major requirements** | **46** |
| CHEM 1A, 1B, 102, 106, 110A, 110B, 111, 123, 124, 128A, 128B, 129A, 129B, 155 | |
| **B. Additional requirements** | **23** |
| MATH 75, 76, 77; PHYS 4A, 4AL, 4B, 4BL, 4C | |
| **C. Remaining General Education requirements** | **45*** |
| **D. Electives and remaining degree requirements** | **6** |

Recommended: CHEM 130, 140T, 142, 153, 156, 160, 190

**Total ..... 120**

* Of the 51 required General Education units, 3 units will be satisfied by PHYS 4A and 4AL in G.E. Breadth B1, and 3 units of MATH 75 in G.E. Foundation B4. Consult the department chair or faculty adviser for details.

### *Advising Note for Chemistry Majors*

1. No General Education Integration or Multicultural/International course with a CHEM designation may be used to satisfy the General Education requirements for majors in the department.

Transfer students are strongly urged to consult their adviser.

Many of the courses listed in the degree requirements have chemistry or other prerequisites. For that reason, the following four-year sample program leading to a B.S. in Chemistry is provided. This sample program emphasizes the need to take course sequences in mathematics and physics prior to CHEM 110A. In addition, it specifies certain semesters for some courses that are offered only once a year. Finally, this program is constructed in such a way as to leave adequate time for independent study experience (CHEM 190) in the senior year.

If a student wishes to deviate significantly from this sample program, particularly in regard to chemistry, physics, and mathematics requirements, it is very important that an alternate program be developed in consultation with a departmental adviser. Any course substitutions or other changes to degree requirements can only be initiated by submitting a written request to the chair of the Chemistry Department.

| **First Semester — Fall** | *Units* |
|---|---|
| CHEM 1A | **5** |
| MATH 75 | **4** |
| ENGL 1 | **3** |
| General Education | **3** |
| | **15** |

| **Second Semester — Spring** | |
|---|---|
| CHEM 1B | **5** |
| MATH 76 | **4** |
| PHYS 4A, 4AL | **4** |
| General Education | **3** |
| | **16** |

| **Third Semester — Fall** | |
|---|---|
| CHEM 128A | **3** |
| CHEM 129A | **2** |
| MATH 77 | **4** |
| PHYS 4B, 4BL | **4** |
| General Education | **3** |
| | **16** |

| **Fourth Semester — Spring** | |
|---|---|
| CHEM 128B | **3** |
| CHEM 129B | **2** |
| CHEM 102 | **5** |
| PHYS 4C | **3** |
| General Education | **3** |
| | **16** |

| **Fifth Semester — Fall*** | |
|---|---|
| **CHEM 110A | **3** |
| **CHEM 155 | **3** |
| **CHEM 123 | **3** |
| CHEM or other elective | **1** |
| General Education | **5** |
| | **15** |

| **Sixth Semester — Spring** | |
|---|---|
| ***CHEM 110B | **3** |
| ***CHEM 111 | **3** |
| ***CHEM 124 | **2** |
| General Education | **8** |
| | **16** |

| **Seventh Semester — Fall** | |
|---|---|
| **CHEM 106 | **4** |
| Chemistry or other elective | **3** |
| CHEM 190 (recommended) or other elective | **3** |
| General Education | **4** |
| | **14** |

| **Eighth Semester — Spring** | |
|---|---|
| CHEM 190 (recommended) or other elective | **3** |
| General Education | **9** |
| | **12** |

**Total ..... 120**

* It is important to fulfill the upper-division writing skills requirement by exam or *W* class during the junior year.
**Offered fall semester only.
***Offered spring semester only.

## Bachelor of Arts in Natural Sciences Degree Requirements

David M. Andrews
*Program Coordinator*
559.278.2412

### *Chemistry Option*

The B.A. in Natural Sciences serves as a waiver program for the Single Subject Teaching Credential in Science. With this credential you are able to teach any introductory science class, i.e., earth, general, life, or physical science along with the courses in your chosen emphasis. Students interested in teaching chemistry in high school may pursue a B.A. in Chemistry or a B.A. in Natural Sciences with a chemistry option (see specific course requirements in the copy that follows). For additional information, see the listing under *Science and Math — Interdisciplinary.*

| | *Units* |
|---|---|
| **Core requirements** | **37** |
| *Biology* | (12) |
| BIOSC 1A, 1B, 130 | |
| *Chemistry* | (10) |
| CHEM 1A, 1B | |
| *Geology*[1] | (8) |
| GEOL 1 and 3 (or 15), 168 | |
| *Natural Science* | (3) |
| NSCI 106 | |
| *Physical Science* | (4) |
| PSCI 21 | |
| **Chemistry Option** | **39** |
| PHYS 2A, 2B[2] | (8) |
| PSCI 168 or GEOL 155 | (3) |
| MATH 75 | (4) |
| MATH 76 | (4) |
| CHEM 128A | (3) |
| CHEM 102, 108*, 128B, 129A, 155* | (17) |
| **General Education requirements** | **51** |
| **Electives and remaining degree requirements**[3,4] | **5** |
| **Total**[3] | **120** |

* Offered fall semester only.

### *Advising Notes for the Natural Sciences Major*

1. GEOL 15 is part of the Humans and the Natural Environment Cluster. See the *Natural Science Interdisciplinary Courses* section in this catalog. GEOL 15 is equivalent to GEOL 1 and 3.
2. Substitutions may be made with the permission of the appropriate department chair. PHYS 4A-B-C with labs 4AL, 4BL is recommended instead of PHYS 2A-B for those students well-prepared for physics.
3. This total assumes that students in this option will maximize the 12 units required for the major that also may be applied to fulfill General Education requirements as follows: CHEM 1A (3 units), BIOSC 1A or BIOL 15 (3 units), GEOL 168 (3 units), and MATH 75 (3 units). Consult your major adviser for details.

4. Students should be sure to take sufficient upper-division units in their General Education courses and electives to satisfy the graduation requirements of 40 upper-division units and upper-division writing skills.

## Chemistry Minor

A Minor in Chemistry for a bachelor's degree requires at least 21 units, of which at least 7 are upper division. Specific course requirements are General Chemistry (CHEM 1A and 1B or 3A), Organic Chemistry (CHEM 8 and 109 or 128A-B and 129A), and Quantitative Analysis (CHEM 105).

Those students requiring additional upper-division chemistry units may choose from courses such as: CHEM 125, 150, 151, 153, 155, and 156.

*Note:* The Chemistry Minor also requires a 2.0 GPA and 6 upper-division units in residence.

## Graduate Program

The mission of the graduate program in chemistry is guided by the mission of the university; it seeks to provide comprehensive undergraduate and graduate degree instruction for qualified students, and to contribute to the needs and well being of the people of the San Joaquin Valley and California.

The California State University, Fresno graduate program in chemistry is primarily oriented toward two groups of students: students who are preparing themselves for employment in chemistry-based occupations (including teaching) and students interested in additional training in chemistry and biochemistry to prepare for advanced Ph.D. graduate work.

For students in the first category, the program stresses strengthening the student's chemistry background while also providing advanced training in both theory and research — training that is very beneficial in today's competitive job market. Furthermore, the program also strives to meet local and regional needs for individuals with advanced training in chemistry and biochemistry, needs that are strongly tied to the agricultural nature of the valley.

For students in the second category, the program's emphasis on improving chemistry background and basic research skills prepares students for work at the Ph.D. level and enhances their chances for success.

## Master of Science Degree Requirements

The Master of Science degree program in Chemistry assumes undergraduate preparation equivalent to a California State University, Fresno B.S. in chemistry. Each new student is required to take the Diagnostic Placement Examinations in four fields of chemistry (physical, organic, analytical, and inorganic or biochemistry) to provide a basis for program planning. These are taken at the beginning of the first semester of residence. Twenty-one of the 30 units required for the degree must be in chemistry.

(See also *Admission to Graduate Standing, Advancement to Candidacy, Program Requirements,* and *Criteria for Thesis and Project.)*

## Graduate-Level Writing Proficiency Requirement

The completion of the following two components will satisfy the writing requirement:

1. successful completion of CHEM 260 with a grade of ***B*** or better, and
2. completion of a formal paper on the student's research to be submitted at the beginning of the fall semester of the second year. The paper should be of sufficient length (at least 2,000 words) to allow proper evaluation by a two-member review committee that includes the research director.

## Master of Science Program Development

Under the direction of a graduate adviser, each student prepares and submits a coherent program individually designed according to Plan A or Plan B listed in the copy that follows. Other courses may be specified after examination of the student's record and performance on the departmental diagnostic examinations.

*Plan A*

| *M.S. Degree with Thesis* | *Units* |
|---|---|
| Courses in chemistry, including at least 24 units in 200 series (see *specific requirements)* | **24** |
| Approved electives in chemistry or related fields | **6** |
| **Total** | **30** |

Specific requirements: CHEM 201 (1 unit); 280 (at least 2 units); 295 (2 units); 299 (4 units); and 3 units each from 4 of the 5 following groupings: (i) CHEM 211 or 215, (ii) 220 or 222, (iii) 225, 226, or 227, (iv) 230 or 235, (v) 241A or 242. CHEM 260 recommended.

Other courses may be specified after examination of the student's record and his or her performance on the departmental diagnostic examinations.

*Plan B*

| *M.S. Degree with Comprehensive Examination* | *Units* |
|---|---|
| Courses in chemistry, including at least 24 units in 200 series (see *specific requirements)* | **24** |
| Approved courses in chemistry or related fields may include biology, engineering, geology, mathematics, physics, etc.) according to the student's objective | **6** |
| **Total** | **30** |

Specific requirements: CHEM 201 (1 unit); 280 (at least 2 units); 295 (2 units); and 3 units each from 4 of the 5 following groupings: (i) CHEM 211 or 215, (ii) 220 or 222, (iii) 225, 226, or 227, (iv) 230 or 235, (v) 241A or 242.

Other courses may be specified after examination of the student's record and his or her performance on the departmental diagnostic examinations.

Instead of a thesis, a student must successfully complete a final comprehensive examination consisting of two parts: (a) a general written examination in chemistry; (b) an examination dealing with a specific area of chemistry. See department for *Policy Statement — Plan B Comprehensive Examination.*

## Biotechnology Certificate Program

California State University, Fresno offers a Certificate of Advanced Study Program in Biotechnology. This intensive one-year postbaccalaureate program emphasizes molecular biology and a wide range of laboratory skills at the forefront of modern biotechnology. The biotechnology field is growing rapidly, and as new products and applications are commercialized, there is increased need for highly skilled personnel capable of working in both research and production areas. Enrollment is limited to 12 to 15 students per year, who work closely with faculty in a variety of lecture and laboratory courses. Among the techniques studied are purification of biological macromolecules, gene splicing, DNA sequencing, culturing

of mammalian cells, hybridoma production, and plant cell culturing and cloning.

The Certificate Program can lead to potential careers in expanding fields, such as drug and hormone production in the pharmaceutical industry, monoclonal antibody production for medical diagnostics, crop improvement, industrial bioprocessing and medical research. The program also provides a background for further postgraduate studies in fields such as biochemistry, molecular biology and agricultural biotechnology. Some of the courses may also be used at California State University, Fresno as components of master's degree programs in biology, chemistry, plant science, and related departments.

Courses include: Molecular Biology (BIOL/CHEM 241A-B), Techniques in Protein Purification (BIOL/CHEM 242), Nucleic Acid Technology Lab (BIOL/CHEM 243), Cell Culture/Hybridoma Laboratory (BIOL/CHEM 244), Micropropagation (PLANT 108), and Seminar in Molecular Biology/Biotechnology (BIOL/CHEM 248).

## COURSES

### *Chemistry (CHEM)*

**CHEM 1A. General Chemistry 1A (5)**
Prerequisites: high school chemistry or CHEM 15R; G.E. Foundation B4 (except for students with declared majors in the College of Science and Mathematics). CHEM 1A not open to students with credit in CHEM 1B. Fundamental principles of chemistry, including the wave mechanical model of the atom, chemical bonding and structure, valence bond, VSEPR and molecular orbital theory; stoichiometry, thermochemistry, oxidation-reductions, and states of matter. G.E. Breadth B1. (4 lecture, 3 lab hours)* (CAN CHEM 2)

**CHEM 1B. General Chemistry 1B (5)**
Prerequisite: CHEM 1A with a grade of *C* or better. Acid-base theory; chemical kinetics; equilibrium (acid-base, hydrolysis, and solubility); thermodynamics, electrochemistry; selected topics in nuclear chemistry, coordination chemistry, and/or chemistry of selected groups. (3 lecture, 6 lab hours)* (CAN CHEM 4)

**CHEM 3A. Introductory General Chemistry (4)**
Prerequisite: G.E. Foundation B4 (except for students with declared majors in the College of Science and Mathematics). No credit for CHEM 3A after 1A. High school chemistry or CHEM 15R recommended. For applied science and nonscience majors. Composition of matter and physical and chemical changes; fundamental laws and principles; atomic and molecular structure; acid-base theory, redox and equilibria; qualitative and quantitative theory and techniques. G.E. Breadth B1. (3 lecture, 3 lab hours)*

**CHEM 3B. Introductory Organic and Biochemistry (3)**
No credit for CHEM 3B to students with credit in 1B. Primarily for students in health-oriented professions; not a substitute for CHEM 8. Prerequisite: CHEM 3A. Introduction to the basic concepts of organic and biochemistry. Structure and behavior of organic and biological compounds, metabolism, and regulation.

**CHEM 8. Elementary Organic Chemistry (3)**
Not open to chemistry majors. Recommended for students requiring a one-semester course in the field. Prerequisite: CHEM 1A or 3A. Lectures, discussions, and demonstrations of fundamental principles; structure and chemical behavior of organic compounds.

**CHEM 10. Chemistry and Society (4)**
Not open to students with credit in college chemistry; for nonscience majors. Prerequisite: G.E. Foundation B4 (except for students with declared majors in the College of Science and Mathematics). The significance of chemical principles in contemporary society; benefits and hazards relative to areas such as energy, health, diet, environment, and agriculture. G.E. Breadth B1. (3 lecture, 2 lab hours)* (Formerly CHEM 1)

**CHEM 15R. Preparation for Chemistry (2)**
Prerequisite: one year of high school algebra. Recommended for students without high school chemistry who are interested in taking additional chemistry or science courses. Basic principles and concepts of chemistry with an emphasis on problem solving. Preparation for CHEM 1A and CHEM 3A. *CR/NC* grading only. Not applicable to baccalaureate degree requirements. (Formerly CHEM AR)

**CHEM 102. Quantitative Analytical Chemistry (5)**
For chemistry majors; recommended for other science majors. Prerequisites: CHEM 1B (with a grade of *C* or better) and 128A. Students with credit in a similar lower-division quantitative analysis course will receive only one additional unit of credit. Introduction to principles and methods of analytical chemistry. (3 lecture, 6 lab hours)*

**CHEM 105. Quantitative Analysis Laboratory (4)**
Not open to chemistry majors. Prerequisites: CHEM 1A or 3A. Laboratory study of principles and methods of applied quantitative analysis. (2 lecture, 6 lab hours)*

**CHEM 106. Analytical Measurements Laboratory (4)**
Prerequisites: CHEM 102 (with a grade of *C* or better), 108 or 110A, or permission of instructor. Principles and methods of analytical measurements of organic and inorganic substances by instrumental and non-instrumental techniques. (2 lecture, 6 lab hours) (Fall semester)*

**CHEM 108. Introductory Physical Chemistry (4)**
Prerequisites: MATH 76 (MATH 77 strongly recommended), CHEM 8 or 128A, and PHYS 2A and 2B or 4A, 4AL, 4B, 4BL, and 4C. Basic treatment of gas laws, thermodynamics, phase equilibria, properties of solutions, kinetics, and spectroscopy. (Fall semester)

**CHEM 109. Elementary Organic Chemistry Laboratory (3)**
Not open to chemistry majors. Prerequisite: CHEM 8 or 128B or concurrently. Laboratory study of the carbon compounds with coordinating lectures. (1 lecture, 6 lab hours)* (Spring semester)

**CHEM 110A-B. Physical Chemistry (3-3)**
Prerequisites: MATH 77; CHEM 1B, 8 or 128A; CHEM 110A requires PHYS 4B; CHEM 110B requires PHYS 4C or permission of instructor. Mathematical treatment of the laws of thermodynamics, reaction kinetics, elementary statistical and quantum mechanics, properties of solutions, kinetic theory of gases, crystal structure, molecular structure, and nuclear chemistry. (CHEM 110A fall semester; CHEM 110B spring semester)

**CHEM 111. Physical Chemistry Laboratory (3)**
Prerequisite: CHEM 110B or concurrently, CHEM 102. May not be taken concurrently with 106. Techniques of physical measurements, error analysis and statistics; ultra-violet, infrared, and nuclear magnetic resonance spectroscopy; dipole moments, viscosity, calorimetry, kinetics, phase dia-

* In all lab courses, the wearing of approved safety glasses is mandatory.

grams, thermodynamic measurements, and report writing. (1 lecture, 6 lab hours) (Spring semester)*

**CHEM 123. Advanced Inorganic Chemistry (3)**
Prerequisites: CHEM 1B, 102 and 110A (or concurrently). Treatment of ionic and covalent bonding, atomic structure, molecular structure, and reaction mechanisms. Introduction to visible and infrared spectroscopy of transition metal complexes, special topics. (Fall semester)

**CHEM 124. Synthesis and Characterization (2)**
Prerequisite: CHEM 123 or concurrently. Techniques of preparation to include high temperature reactions, vacuum line and glove box preps, nonaqueous syntheses, solid state reactions. Emphasis on structural characterizations using instrumental methods. (6 lab hours) (Spring semester)*

**CHEM 125. Applied Analytical Techniques (3)**
Prerequisites: CHEM 8 or 128A and CHEM 102 or 105. Analytical techniques and their applications in clinical, environmental, agricultural, forensic, and bioscience laboratories. (2 lecture, 3 lab hours)*

**CHEM 127. Organic Problems (1)**
Prerequisites: CHEM 8 or 128A; 128B concurrently. Designed to review organic chemistry, in particular for those students who have taken only a brief course in organic chemistry. ***CR/NC*** grading only; not applicable to the requirements of a major in chemistry.

**CHEM 128A-B. Organic Chemistry (3-3)**
For chemistry majors; recommended for premedical students and other science majors. CHEM 128A not open for credit to students with credit in CHEM 8. Prerequisites: CHEM 1B; for CHEM 128B: CHEM 128A with a grade of ***C*** or better. Introduction to structure and reactivity of principal classes of organic compounds with emphasis on theory and mechanism.

**CHEM 129A-B. Organic Chemistry Laboratory (2-2)**
Prerequisites: CHEM 128A or concurrently for 129A; CHEM 128B or concurrently ***and*** CHEM 129A for 129B. CHEM 129A must be taken before CHEM 129B. Laboratory study of the methods, techniques, syntheses, and instrumentation or representative classes of organic compounds; introduction to research techniques by way of independent projects; introduction to qualitative organic analysis. (6 lab hours)*

**CHEM 130. Organic Analysis (3)**
Prerequisites: CHEM 102, 128B, 129B. Characterization of organic compounds through study of chemical and physical properties; application of spectroscopy, chromatography and functional group analysis to elucidation of structure. (1 lecture, 6 lab hours)*

**CHEM 139. Chemistry and the Consumer (3)**
Prerequisite: CHEM 3B, 8, or 128A. The impact of chemistry on society and individual lives. Topics selected from: foods as chemicals, food additives, drugs and medication, petrochemistry and the source of chemicals, pesticides and agricultural chemicals, chemical ethics, and current topics of interest.

**CHEM 140T. Topics in Chemistry (1-4; max total 6 if no area repeated)**
Prerequisite: permission of instructor. Seminar covering special topics in one of the areas of chemistry: analytical, biochemistry, inorganic, organic, physical. Some topics may have a laboratory.

**CHEM 142. Introduction to Biotechnology (3)**
Prerequisite: CHEM 150 or permission of instructor. Emphasizes the principles and industrial utilization of recombinant DNA, monoclonal antibodies, enzyme and cell immobilization, fermentation technology, and downstream processing.

**CHEM 150. General Biochemistry (3)**
Prerequisite: CHEM 8. (CHEM 150 and 153 together constitute a year sequence.) Chemistry and metabolism of basic cellular constituents including carbohydrates, lipids, proteins, and nucleic acids.

**CHEM 151. General Biochemistry Laboratory (2)**
Prerequisites: CHEM 8, 105, 109, 150 (or concurrently). Chemical and physical properties of naturally occurring compounds; introduction to techniques of chromatography, polarimetry, electrophoresis, photometry, and enzymology. (6 lab hours)*

**CHEM 153. Physiological Chemistry and Metabolism (3)**
Prerequisite: CHEM 150 or 155. Continuation of CHEM 150 or 155. Intensive discussion of the degradation and biosynthesis of major cellular constituents; energy metabolism; control of metabolic processes and pathological implications in mammalian systems. (Spring semester)

**CHEM 155. Fundamentals of Biochemistry (3)**
Primarily for chemistry majors; recommended for premedical students and graduate students in the sciences. Prerequisite: CHEM 128B. (CHEM 155 and 153 together constitute a year sequence.) Structure, function, and metabolism of chemical entities in living systems. (Fall semester)

**CHEM 156. Biochemical Laboratory Techniques (3)**
Prerequisites: senior standing or permission of instructor; CHEM 150 or 155 (or concurrently), 102 or 105, 109 or 129A. Provides the student with a range of techniques and methodology appropriate to the study or phenomena at the biochemical, cellular, and organismic levels. Satisfies the senior major requirement for the B.A. in Chemistry. (1 lecture, 6 lab hours) (Spring semester)*

**CHEM 160. Research Techniques (3)**
Concepts in the design of experiments. Development of practical research skills through the planning and undertaking of a short laboratory project. Satisfies the senior major requirement for the B.S. in Chemistry. (1 lecture, 6 lab hours)*

**CHEM 170. Chemistry in the Marketplace (3)**
Not open to chemistry majors. Prerequisites: G.E. Foundation and Breadth Area B. The impact of chemistry and chemicals on society and individual lives. G.E. Integration IB. (3 lecture hours)

**CHEM 171. Fireworks, Gemstones, and Dyes: The Science of Color (3)**
Primarily for non-science majors. Prerequisites: G.E. Foundation and Breadth Area B. The chemistry and physics behind the color of objects and color perception, and the interaction of light with matter. G.E. Integration IB. (2 lecture, 3 lab hours)

**CHEM 190. Independent Study (1-3; max total 6)**
Prerequisite: permission of instructor. See *Academic Placement — Independent Study*. Approved for ***RP*** grading.

* In all lab courses, the wearing of approved safety glasses is mandatory.

## GRADUATE COURSES

(See *Catalog Numbering System.)*

### *Chemistry (CHEM)*

**CHEM 201. Chemistry Laboratory Teaching Techniques (1)**
Laboratory safety, lab lecture techniques, equipment setups, grading, etc. Primarily for teaching assistants in chemistry.

**CHEM 211. Chemical Thermodynamics (3)**
Prerequisites: CHEM 110A, 110B, 111. Principles of thermodynamics; application to chemical problems; introduction to statistical methods, calculation of thermodynamic functions from spectroscopic data.

**CHEM 212. Chemical Applications of Group Theory (1-2; max total 2)**
Prerequisites: CHEM 110A, 110B. Introduction to symmetry operations, point groups and their properties. Application of group theory to chemical problems such as; selection rules for electronic, IR, Raman and microwave activity, molecular orbital theory, transition metal complexes, hybridization, and other chemical topics.

**CHEM 215. Quantum Chemistry (3)**
Prerequisite: graduate standing. Seminar on recent advances in quantum mechanics; chemical bonding, and atomic and molecular spectroscopy.

**CHEM 220. Theoretical Inorganic Chemistry (3)**
Prerequisites: CHEM 110A, 110B, 123. Seminar on theoretical inorganic chemistry emphasizing structure and bonding of inorganic and coordination compounds, valence bond, molecular orbital and ligand field theories; correlation of structure and reactivity.

**CHEM 222. Advances in Inorganic Chemistry (3)**
Prerequisites: CHEM 110A, 110B, 123, 128B. Seminar on recent advances in inorganic chemistry. Topics may include, but are not limited to, organometallic chemistry, solid-state chemistry, nonmetallic complexes, and the chemistry of rare-earth compounds.

**CHEM 225. Separation Methods in Chemistry (1-3)**
Prerequisites: CHEM 106 and 129B. Seminar on the theory, application, and literature of various separation methods for organic and inorganic analysis. May include laboratory.

**CHEM 226. Electrochemistry (1-3)**
Prerequisite: CHEM 106. Seminar on the theory, application, recent developments, and literature of electrochemistry and electrochemical methods of organic and inorganic analysis. May include laboratory.

**CHEM 227. Analytical Spectroscopy (1-3)**
Prerequisites: CHEM 106, 110A, 110B, or permission of instructor. Theory, instrumentation, and application. Recent developments and literature of spectroscopic techniques. May include laboratory.

**CHEM 230. Advanced Organic Chemistry (3)**
Prerequisites: CHEM 128B, 129B. Seminar on recent advances in organic chemistry including reaction mechanisms and synthetic applications with references to current literature.

**CHEM 235. Physical Organic Chemistry (3)**
Prerequisites: CHEM 110A, 110B, 128B. Seminar in application of modern theoretical concepts to the chemical and physical properties of organic compounds.

**CHEM 240T. Topics in Advanced Chemistry (1-3)**
Seminar covering special topics in one of the areas of chemistry: analytical, biochemistry, inorganic, organic, physical. Some topics may have a laboratory.

**CHEM 241A-B. Molecular Biology I-II (3-3)**
(Same as BIOL 241A-B.) Prerequisites: BIOSC 140A-B, CHEM 150 or 155, or permission of instructor. BIOL/CHEM 241A is prerequisite for BIOL/CHEM 241B. Current topics in molecular biology are addressed, including protein and nucleic acid structure, DNA replication, transcription, translation, prokaryotic and eukaryotic regulation, mechanisms of exchange of genetic material, and recombinant DNA technology.

**CHEM 242. Techniques in Protein Purification and Analysis (3)**
(See BIOL 242.) Prerequisite: CHEM 151 or 156 or permission of instructor. Corequisite: BIOL/CHEM 241A. Deals with the technologies relevant to protein isolation, purification, analysis, immobilization, and modification in micro and macro quantities. (1 lecture, 6 lab hours)

**CHEM 243. Nucleic Acid Technology Lab (3)**
(Same as BIOL 243.) Prerequisites: BIOL/CHEM 241A and 242. Corequisite: BIOL/CHEM 241B. A lecture/laboratory course focusing on the technologies used in nucleic acid chemistry; specifically, synthesis, translation, mutagenesis, and genetic engineering. (1 lecture, 6 lab hours)

**CHEM 244. Cell Culture and Hybridoma (3)**
(See BIOL 244.) Prerequisites: MICRO 185 or PHYAN 160 and 160L. The theory and practice of *in vitro* propagation of eukaryotic cells, including growth characteristics, metabolic requirements and genetic analysis. Cloning, fusion and generation of monoclonal antibody (hybridoma) are presented relative to cultured cell biology and application to biotechnology. (1 lecture, 6 lab hours)

**CHEM 248. Seminar in Molecular Biology and Biotechnology (1-2; max total 4)**
(Same as BIOL 248.) Prerequisite: admission into the Biotechnology Certificate Program. Reviews and reports on current literature in various aspects of biotechnology and molecular biology.

**CHEM 260. Advanced Research Techniques (3)**
Prerequisites: classified standing or permission of the instructor. Advanced concepts in experimental design. Development of practical research expertise and communication skills through the planning, completion, and presentation (both written and oral) of a short laboratory project. (1 lecture, 6 lab hours)

**CHEM 280. Seminar in Chemistry (1; max total 3)**
Approved for ***RP*** grading.

**CHEM 290. Independent Study (1-3; max total 6)**
See *Academic Placement — Independent Study*. Approved for ***RP*** grading.

**CHEM 295. Research (2)**
Prerequisite: permission of instructor. Independent investigations of an advanced character for the graduate student with adequate preparation. Approved for ***RP*** grading. (May include conferences, laboratory, library.)

**CHEM 299. Thesis (4)**
Prerequisite: See *Criteria for Thesis and Project*. Preparation, completion, and submission of an acceptable thesis for the master's degree. Approved for ***RP*** grading.