2008-2009 announcement

College of Chemistry

Chemical Engineering, Chemistry, and Chemical Biology Majors

University of California, Berkeley

Academic Calendar 2008-09

Fall Semester 2008

Tele-BEARS Begins	April 14	Monday
Fee Payment Due	August 15	Friday
Fall Semester Begins	August 21	Thursday
Welcome Activities	August 25-26	Monday-Tuesday
Instruction Begins	August 27	Wednesday
Labor Day Holiday	September 1	Monday
Veterans Day Holiday	November 11	Tuesday
Thanksgiving Holiday	November 27-28	Thursday-Friday
Instruction Ends	December 10	Wednesday
Final Examinations	December 13-20	Saturday-Saturday
Fall Semester Ends	December 20	Saturday
Winter Holiday	December 25-26	Thursday-Friday
New Year's Holiday	December 31-January 1, 2009	Wednesday-Thursday

Spring Semester 2009

Tele-BEARS Begins	October 20, 2008	Monday
Spring Semester Begins	January 13	Tuesday
Fee Payment Due	January 15	Thursday
Martin Luther King Jr. Holiday	January 19	Monday
Instruction Begins	January 20	Tuesday
Presidents' Day Holiday	February 16	Monday
Spring Recess	March 23-27	Monday-Friday
César Chávez Holiday	March 27	Friday
Cal Day	April 18	Saturday
Instruction Ends	May 11	Monday
Final Examinations	May 14-21	Thursday-Thursday
Spring Semester Ends	May 21	Thursday

Summer Sessions 2009

Memorial Day Holiday	May 25	Monday
First Six-Week Session	May 26-July 2	Tuesday-Thursday
Ten-Week Session	June 8-August 14	Monday-Friday
Eight-Week Session	June 22-August 14	Monday-Friday
Independence Day Holiday	July 3	Friday
Second Six-Week Session	July 6-August 14	Monday-Friday
Three-Week Session	July 27-August 14	Monday-Friday

Contents

The College

Department of Chemical Engineering

Department of Chemistry

General Information

Announcement of the College of Chemistry, University of California, Berkeley, 2008-09.
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To Prospective Students

Chemistry and chemical engineering are areas of opportunity for solving a number of major world problems. Making new materials for new applications, developing new drugs and food supplies and synthesizing new products biochemically, learning the chemical nature of biological materials, recovering and utilizing dwindling energy and mineral resources, and improving our environment all depend centrally upon chemistry and chemical engineering. Students entering either of these fields today will have exciting careers addressing fundamental scientific problems in chemistry, applying chemical concepts to problems in related scientific areas, and using established concepts to pioneer new technologies.

Both departments in the College of Chemistry rank among the most prominent in their fields, and both are renowned for their breadth of activity in a diverse range of subdisciplines and applications. Nowhere else will you find such a wide selection of offerings in chemical sciences and applications. Four centers of excellence — in organic synthesis, theoretical chemistry, catalysis, and analytical biotechnology — provide special opportunities for both undergraduate and graduate research. The college is continually modernizing its facilities, and new equipment arrives constantly. Facilities at the Lawrence Berkeley National Laboratory are available to many of the college's research programs. The California Institute for Quantitative Biomedical Research (QB3) provides a dynamic interdisciplinary environment in which students and faculty in the college collaborate with their colleagues in the physical, mathematical, and biological sciences and in engineering to conduct cutting-edge research into biological problems. With only two departments, the college is a relatively small and comfortable place in which to work. Like anywhere else, the faculty members have many demands on their time, but students are able to develop close and satisfying contacts with a number of faculty members during their stay in the college.

We encourage you to explore our college's offerings, and we look forward to serving you.

Clayton H. Heathcock
Interim Dean, College of Chemistry


SATHER GATE

The College of Chemistry

The College of Chemistry was established as an instructional unit within the University of California by an Act of the State Legislature in 1872. It has continued to exist as a separate college and now includes the Departments of Chemistry and of Chemical Engineering, both of which are among the most highly ranked departments in their fields.

The college combines an outstanding faculty with modern laboratories and lecture halls, a strong support staff, and a long tradition of excellence. Among the 79 faculty members are one Nobel laureate, two Fellows of the Royal Society of London, 27 members of the National Academy of Sciences, and seven members of the National Academy of Engineering. (This list includes eight faculty members who are Professors of the Graduate School or active emeriti.) The breadth of interests and dedication to research among the faculty provide students with a chance to become acquainted with the latest scientific advances and thought.

The college has a number of active seminar programs in which distinguished visitors from all over the world describe their current work. The college also attracts many outstanding scientists from other universities for longer engagements as visiting professors or sabbatical-leave visitors.

Advanced undergraduate and graduate students have opportunities to do research in synthetic and structural chemistry of organic and inorganic compounds, chemistry of natural products, theoretical chemistry, nuclear chemistry, physical chemistry, organometallic chemistry, chemical biology, solid-state and surface chemistry, catalysis, process design and control, product development, polymers, food processing, and biochemical engineering.

The college offers advising services to students at all levels. In a recent report on lower division education by the Associated Students of the University of California, the College of Chemistry was rated highest among all of Berkeley's colleges for the ease with which students could "choose courses, professors, and understand how best to meet academic and career needs."

General Information

Living Environment

The campus, the San Francisco Bay Area, and other nearby areas of Northern California provide an unparalleled opportunity for cultural and recreational pursuits.

The Berkeley campus is situated directly east of the Golden Gate, overlooking San Francisco and the major portion of the Bay. The view from the Berkeley campus is one of the most scenic in the world.

The Bay Area provides an abundance of cultural events through its museums, theaters, symphonies, opera, ballet, jazz festivals, and other performing arts. There is a great variety of cultural events on the Berkeley campus itself and the campus is home to outstanding art and anthropology museums.

Virtually every cuisine can be enjoyed in the famous restaurants of Berkeley, Oakland, and San Francisco. The scenic Napa Valley, just one hour's drive from Berkeley to the north, produces some of the best wines of the United States; most wineries welcome visitors and provide free tasting rooms. Professional sports events of every kind abound in the area, and the mild climate provides a year-round opportunity for outdoor sports. Because of the tempering action of the ocean, hot days are relatively rare in Berkeley, and snow creates headlines.

Northern California enjoys a wealth of opportunities for those interested in hiking, camping, skiing, sailing, or just sightseeing. A few hours to the south of the Bay Area along the coast are Monterey, Carmel, and the Big Sur area, where the coast range reaches the ocean. To the north the coast range encompasses the rocky Mendocino Coast and stands of giant redwoods and evergreen chaparral. The state's volcanic past is evident at Lassen National Park, Mt. Shasta, and Clear Lake. In the Bay Area itself, Mount Diablo, Mount Tamalpais, Muir Woods, the Golden Gate National Recreation Area, and the Point Reyes National Seashore provide many recreational facilities. Within walking distance of the campus are Wildcat Canyon and Tilden Parks, which provide both pleasant picnic spots and long walks in natural areas.

Housing

There is a wide variety of housing on and off the Berkeley campus. All new, incoming fall freshmen who apply for housing by the deadline are guaranteed housing in the residence halls. Admission to Berkeley does not guarantee housing reservations. Students should acquaint themselves well in advance of enrollment with the various living arrangements. Students may go to www.housing.berkeley.edu for more information or write to Residential and Student Service Programs, University of California, Berkeley, 2610 Channing Way #2272, Berkeley, CA 94720-2272.

Student Activities

A Berkeley education does not begin and end in the classroom. Through professional societies, campus student organizations, and publications, students are encouraged to discuss chemical engineering and chemistry with fellow students, faculty, and practicing chemical engineers and chemists.

Student groups affiliated with the American Chemical Society and the American Institute of Chemical Engineers conduct active programs throughout the school year. These organizations give students a chance to meet others with similar interests, tour industrial laboratories, and learn more about the college and the professional activities of chemists and chemical engineers.

Chemical engineering students in the honors group are considered for election to Tau Beta Pi, the engineering honorary society. Women students may be elected to Iota Sigma Pi, an honorary society for women in chemistry. The professional fraternity in chemistry, Alpha Chi Sigma, elects its members from among student chemists and chemical engineers.

Other campus groups include BESSA (Black Engineering and Science Students Association), the Society of Women Engineers, and HES (Hispanic Engineers and Scientists). In addition, students interested in technical journalism are encouraged to participate in publication of *The California Engineer,* the student engineering journal. This participation includes all aspects of magazine production, from typesetting and layout to advertisement sales.

The activities of both the professional and the scholastic engineering societies are coordinated by the Engineers Joint Council (EJC), which is made up of representatives from each group. Activities of EJC and its member societies include technical and social meetings, field trips, tutoring services, discussion of academic and professional issues, and the annual campus Engineers' Week.

Student Services

Career Center/Recruiting

The Career Center (career.berkeley.edu) instructs undergraduate and graduate students about the career planning and job search process and assists students interested in applying to graduate school. The Career Center connects students with employers and nationwide graduate and professional schools.

In addition to individual counseling, Career Center services include:

- on-campus recruiting program for graduating students with more than 500 employers participating;
- listings for full-time positions and student jobs and internships;
- career, internship/summer, and graduate school fairs; special workshops and programs for engineering students;
- mailing lists for receiving specialized career information;
- online and print materials for researching employers and graduate schools;
- web-based letter of recommendation service supporting application to graduate school or for academic employment; and
- graduate school admission test material.

For more information, including a calendar of activities, job and internship listings, and staff list, consult career.berkeley.edu or contact the office at 2111 Bancroft Way, between Fulton St. and Shattuck Ave., (510) 642-1716. Hours are 9 a.m.-5 p.m., Monday-Friday.

In addition to the Career Center, the college annually hosts a number of industrial recruiters seeking Ph.D. and postdoctoral students.

Berkeley Programs for Study Abroad

While progressing toward undergraduate degrees in the College of Chemistry, undergraduates have opportunities to earn credit toward the degrees while studying abroad. College of Chemistry undergraduates are encouraged to participate in Berkeley Programs for Study Abroad (BPSA).

For information about these programs contact an adviser in the Berkeley Programs for Study Abroad Office, University of California, Berkeley, 160 Stephens Hall #2302, Berkeley, CA 94720-2302, (510) 642-1356. E-mail eapucb@berkeley.edu or visit ias.berkeley.edu/bpsa.

Financial Aid

The University of California, Berkeley offers a wide variety of financial aid programs to help undergraduate students meet their educational expenses.

There are several scholarships restricted to students in the College of Chemistry; some are based on merit and are independent of financial need. Students who apply through the Office of Financial Aid will automatically be considered for these scholarships.

Students may contact the Office of Financial Aid, University of California, Berkeley, 201 Sproul Hall #1960, Berkeley, CA 94720-1960, (510) 642-6442, for answers to any questions about application deadlines, processing, and eligibility for financial aid, or visit uga.berkeley.edu/fao.

The California Alumni Association offers merit-based leadership scholarships, some of which give preference to chemistry, chemical biology, or chemical engineering students. Contact the California Alumni Association Scholarship Office at (510) 642-7281 for more information, or go to www.alumni.berkeley.edu/Scholarships.

Disabled Students' Program

The Disabled Students' Program (DSP) is located at 260 César Chávez Student Center, (510) 642-0518; TTY/TDD, (510) 642-6376. Students who have visual, hearing, mobility, or physical disabilities, or learning or other non-apparent disabilities, may contact DSP for information about services or visit dsp.berkeley.edu.

Alumni, Development, and Public Affairs

All graduates are invited to join the college's Chemistry and Chem*ical* Engineering Alumni Association. No dues are charged. Students also can become involved with Alumni Association activities while they are still enrolled. The Chemistry and Chem*ical* Engineering Alumni Association provides online mentoring to interested students.

All alumni receive the *News Journal of the College of Chemistry,* a semiannual publication written specifically for them. Current news stories are posted online at chemistry.berkeley.edu. Gatherings of alumni are held annually in the Bay Area and in conjunction with the meetings of the American Chemical Society and the American Institute of Chemical Engineers.

Alumni, as well as parents and friends, are invited to help in maintaining the excellence of the college through financial support and as volunteers. This support is vital in meeting the 66 percent of the college's budget that does not come from the state of California. Private funds have been used, among other things, for undergraduate scholarships, graduate fellowships, the library, facilities, and research.

Facilities

The College of Chemistry complex, a cluster of interconnected buildings, consists of Gilman, Hildebrand, Latimer, Lewis, and Tan Halls, as well as the Giauque Laboratory and Pimentel Hall. Hildebrand and Latimer Halls were completed and equipped in the 1960s and upgraded for seismic safety in 2002. Over the years, a large number of lab and office spaces in both buildings have been renovated to meet current standards for teaching and scientific research. Pimentel Hall, which is used for a number of large undergraduate courses, is one of the most innovative examples of classroom design in the country, utilizing a revolving platform for the preparation of experiments "behind the scenes" while a lecture is in progress. A large television screen allows students in every seat in the hall to follow demonstrations as if they were in the front row. Our newest building, Tan Hall, provides state of the art research space for both chemistry and chemical engineering and an undergraduate computer facility.

The College of Chemistry complex houses the laboratories of individual research groups, shops, analytical facilities, stockrooms, the Chemistry Library, administrative offices, and instructional facilities.

A number of faculty and their research groups are now housed in Stanley Hall, a new facility that fosters interdisciplinary research in the biosciences. The building, located directly across University Drive from the college complex, also houses core research and analytical facilities.

In addition to the excellent research facilities on campus, students have access to facilities in several Divisions of the Lawrence Berkeley National Laboratory (LBNL), particularly the Nuclear Science Division, the Energy and Environment Division, and the Materials and Molecular Research Division.

Student Centers, Computer Facilities, and Libraries

The Bixby Commons is often used as an after-hours study hall for junior and senior undergraduates majoring in chemical biology, chemical engineering, or chemistry.

The College of Chemistry Computer Facility makes available personal computers for use by students in chemical engineering and chemistry courses. The computers provide connection to the campus computer network, as well as stand-alone computing, and they are equipped for graphic displays and for plotting. The facility is open weekdays, and access is arranged through the course instructors.

The Chemistry and Chemical Engineering Library serves the Department of Chemical Engineering and the Department of Chemistry. All major chemical engineering and chemistry databases are available online at www.lib.berkeley.edu/chem, including SciFinder Scholar, DiscoveryGate, CrossFire Beilstein/Gmelin, Compendex, and Web of Science. The library provides access to a growing collection of encyclopedias, dictionaries, and handbooks online, such as the Kirk-Othmer Encyclopedia of Chemical Technology, Ullmann's Encyclopedia of Industrial Chemistry, the CRC Handbook of Chemistry and Physics, the Merck Index, and Perry's Chemical Engineers' Handbook. Students have electronic access to an immense collection of scholarly journals via UC's California Digital Library (CDL) including titles from all of the major science and technology publishers.

Other branch libraries on the campus, such as Physics, Engineering, Biosciences, Natural Resources, and Public Health, supplement the Chemistry and Chemical Engineering Library's collections; links with these and other libraries provide access to a vast amount of information.

College Shops and Instrumentation Facilities

The college's six shops (Electrical Shop, Electronics Shop, Glass Shop, Machine Shop, Student Shop, and Wood Shop) provide a diverse range of highly specialized technical services supporting research and educational activities in the college. The shops provide services in state-of-the-art R&D machining; welding; high-tech equipment and experimental apparatus prototyping, fabrication, and repair; electrical work; data and telecommunication equipment and cabling; electronics; scientific glass-blowing; instruction in shop skills; facilities construction and remodeling; laboratory plumbing; carpentry and construction; cabinet work; HVAC; and precision sheet metal fabrication, as well as consultation in all of these areas.

The **Electronics Shop** diagnoses, repairs, designs, and fabricates highly specialized electronic equipment. Examples of such equipment are emission control units for ion or electron optics, power supplies for electrophoresis in DNA analysis, High Voltage pulse generators for controlling piezo valves, and data acquisition systems.

The **Glass Shop** provides design and fabrication of custom glassware and repair of scientific setups. Some examples of work are optical pumping cells, specialty vacuum lines for atmospheric chemistry, diffusion pumps, electrochemical cells, and quartz cells for catalytic chemistry.

The **Machine Shop** provides college researchers and the University of California at large with design, fabrication, technical support, and repair of all instructional and research mechanical systems. Areas of recent involvement include design and fabrication of instrumentation used in nanotechnology research, which has led to breakthrough advancements in the materials science, biotechnology, and semiconductor industries.

The **Electrical Shop** and the **Wood Shop** work together to design and build the most up-to-date instructional and research laboratories, classrooms, and offices. They also design, fabricate, and install custom fixtures and devices for experimental assemblies.

The **Student Shop** is available for graduate students who can "do-it-themselves." Completion of a short course in the use of the lathe, mill, drill press, band saws, and other tools earns students shop access.

The college is also proud of its instrumentation facilities, including the Nuclear Magnetic Resonance Facility, the X-ray Crystallographic Facility, the Mass Spectrometry Facility, the Computer Graphics Facility, and the Microanalytical Laboratory. All are equipped with state-of-the-art instruments, most of which are available for hands-on use by students when they have acquired the appropriate training.

The **Nuclear Magnetic Resonance Facility** is especially important to students engaged in chemical research. The facility is open 24 hours a day; students run their own experiments. At present, the facility includes five superconducting spectrometers ranging from 300 MHz to 500 MHz for proton NMR. The spectrometers have multinuclear capability to observe most NMR-active nuclei, and are capable of multidimensional experiments. Workstations are available for off-line processing. Some eight additional NMR instruments are available throughout the college. Graduate students who expect to use NMR in their research are trained to use the spectrometers in a special course, offered in the fall semester each year.

The **X-ray Crystallographic Facility** (CHEXRAY) provides single-crystal structure analysis on a service basis. It is also open for use by qualified students and faculty. It is equipped with a Siemens SMART CCD area-detector system and an Enraf-Nonius CAD4 diffractometer, both with low-temperature capability. It maintains in-house computational capability for the structure analyses and free access to the Cambridge Structural Database. A course covering both theory and practice of X-ray Crystallography is taught each spring semester.

The **Mass Spectrometry Facility** houses six mass spectrometers capable of a variety of ionization techniques necessary for the successful analysis of compounds produced in modern synthetic chemistry laboratories. These techniques include fast atom bombardment (FAB), electrospray, and laser desorption/ionization, in addition to the classical electron impact (EI) method. Several of the newer techniques allow molecular weight determination and structural characterization of compounds previously considered intractable by mass spectrometry. In addition, several instruments enable high resolution measurements for accurate mass determination and mass measurements out to 10,000 amu. Tandem mass spectrometry (MS/MS) capabilities are available for sophisticated ion chemistry studies. Included in the facility's instrumentation is a GC/MS available for hands-on use following a brief training session.

The **Computer Graphics Facility** contains several graphics workstations from DEC, IBM, and Stardent useful for both computational chemistry and scientific visualization. Molecular modeling software available in the facility includes InsightII, MacroModel, Quanta, and the Chemistry Viewer for AVS. General scientific visualization software includes AVS, Mathematica, PV-WAVE, and IDL. Hard copy output of graphics created in the facility is available on glossy paper, transparencies, slide, and VHS (video) formats. This facility provides theoretical chemists with sophisticated visualization techniques and synthetic and biological chemists with significant computational capabilities.

The **Microanalytical Laboratory** performs precision analyses on samples submitted by its customers. These analyses are accomplished on combustion analyzers and an atomic absorption instrument. Results are available for samples submitted for routine CHN analyses within 72 working hours. One day a week is set aside for the analysis of air sensitive samples. Requests for determinations of elements other than CHN will be performed within one week, unless notified otherwise.

A large amount of additional analytical equipment, including Fourier-transform infrared, visible and ultraviolet spectrophotometers, and electron paramagnetic resonance spectrometers, is maintained by the college on a community-use basis. Still more research equipment is available in the laboratories of individual research groups. The college also has access to special research facilities, such as the heavy ion linear accelerator and the 88-inch cyclotron at LBNL.

Undergraduate Programs

University of California, Berkeley
College of Chemistry
Undergraduate Majors Office
420 Latimer Hall #1460
Berkeley, CA 94720-1460
(510) 642-3452
chemistry.berkeley.edu

Undergraduates have a choice of the following degree programs:

- **The Bachelor of Science Degree in Chemical Engineering**, intended as preparation for a career in chemical engineering and related disciplines, permits a broad range of interdisciplinary concentrations in such areas as biotechnology, chemical processing, applied physical science, environmental technology, and materials science and technology.
- **The Bachelor of Science Degree in Chemistry** is intended for students who are primarily interested in careers as professional chemists or wish a thorough grounding in chemistry in preparation for professional or graduate school in chemistry and other disciplines.
- **The Bachelor of Science Degree in Chemical Biology** is intended for students who are interested in careers in biochemistry, the biological sciences, medicine, pharmacology, and bioengineering.
- **The Bachelor of Arts Degree in Chemistry**, which is offered through the College of Letters and Science, includes a greater number of humanities and social science courses than the Bachelor of Science Degree and is intended for those interested in careers in teaching, medicine, or other sciences in which a basic understanding of chemical processes is necessary. Students who are interested in the B.A. degree apply for admission to the College of Letters and Science.
- Also, **two B.S. degree joint major programs** (Chemical Engineering and Materials Science and Engineering, and Chemical Engineering and Nuclear Engineering) are offered through the College of Chemistry.

Admission

The filing period for admission applications is November 1-30 for the fall semester of the following year. Applicants must satisfy UC minimum eligibility requirements for admission to the University. See the *General Catalog* for details, or go to catalog.berkeley.edu/undergrad/admission.html. Communications regarding undergraduate admission should be addressed to the Office of Undergraduate Admissions, University of California, Berkeley, 110 Sproul Hall #5800, Berkeley, CA 94720-5800. Students may also call (510) 642-3175 for general admission information or (510) 642-0569 for applications.

The College of Chemistry admits students as beginning freshmen or in advanced standing at the junior level. Admission to the joint major programs (Chemical Engineering and Materials Science and Engineering, and Chemical Engineering and Nuclear Engineering) is open to transfer students but closed to entering freshmen. Continuing students may petition for a change to a joint major program after they attain sophomore standing.

Admission as a Freshman

In addition to satisfying UC minimum eligibility requirements, students preparing for the major in chemistry, chemical biology, or chemical engineering should include in their high school programs: chemistry (one year; AP chemistry recommended); physics (one year); mathematics (four years, including trigonometry, intermediate algebra, and analytic geometry); and a foreign language (two or three years, preferably German, Russian, or French).

Admission as a Transfer Student (Advanced Standing)

The requirements for entry to the University may be met by establishing a good record at another collegiate institution. Transfer applicants must complete at least 60 semester units or 90 quarter units of UC-transferable course work by the end of the spring term before transfer to Berkeley. Students are encouraged to investigate the University-preparatory programs offered by many community colleges throughout California. Up to 70 UC-transferable semester units may be tranferred from a community college.

In addition to satisfying UC minimum eligibility requirements, College of Chemistry transfer applicants are expected to complete, at a minimum, courses equivalent to:

- Chemistry 1A-1B;
- Mathematics 1A-1B;
- Physics 7A (choice of 7A or 8A for chemical biology majors);
- English R1A (plus English R1B for chemistry or chemical biology majors);
- *plus* two additional courses toward the major by the end of the spring term before transfer.

Furthermore, completion of additional chemistry, mathematics, calculus-based physics, and some biology is encouraged. Transfer applicants need grades of B or better in math and science courses to be adequately prepared to continue with the courses of the junior year. *Please note:* Course work taken the summer before enrollment at Berkeley is not considered in the selection of applicants.

Chemical engineering majors are encouraged to complete a course in computer programming for science or engineering students before transfer. Chemistry or chemical biology majors are encouraged to complete a course in quantitative analysis before transfer if it is not included in their general chemistry courses. Chemistry or chemical biology majors who transfer without having covered quantitative analysis are required to take Chemistry 4B, 15, or 105 after transfer.

Community college transfer students should take the organic chemistry sequence at their community colleges, if possible. Completion of a year of organic chemistry (lecture and laboratory), combined with a score in the 75th percentile or higher on the American Chemical Society (ACS) Organic Chemistry Exam will constitute satisfactory completion of Berkeley's Chemistry 112A-112B. Students are encouraged to take the exam through their community colleges if possible.

When completed by the end of the spring term before transfer to Berkeley, the Intersegmental General Education Transfer Curriculum (IGETC) is accepted in satisfaction of the Reading and Composition requirement. However, IGETC does not satisfy the entire Breadth requirement. For chemistry or chemical biology majors, IGETC is also accepted in satisfaction of the Foreign Language requirement.

Degree Requirements

To graduate with a B.S. degree, the student must satisfy the following requirements plus those listed in the departmental undergraduate programs sections (see "Table of Contents").

Entry-Level Writing

The University assumes that students are proficient in English and in writing about academic topics. Fulfillment of the Entry-Level Writing requirement is a prerequisite to enrollment in all freshman reading and composition courses. Students who have not passed the Analytical Writing Placement Exam or otherwise fulfilled the requirement when they enter the University should enroll in College Writing R1A during their first or second semester. College Writing R1A is a six-unit course that satisfies the Entry-Level Writing requirement and a first-level reading and composition course (e.g., English R1A). Detailed information about this University requirement is available in the *General Catalog* (see catalog.berkeley.edu).

American History and Institutions

Nearly all incoming students have already satisfied their American History and Institutions (AH&I) University-wide requirements with course work completed in high school or at another college in the U.S. Students who still need to satisfy their American History and/or American Institutions requirements and are not eligible for international student waivers may do so by completing course work. Courses taken to fulfill these requirements may be taken on a *passed/not passed* basis and will also count toward the Breadth requirement.

UC Berkeley courses that fulfill the AH&I requirements are History 7A, 7B, 130B, 131A, 131B, or 138 for the American History requirement and Political Science 1, 1AC, or 108A for the American Institutions requirement. More information is available at teaching.berkeley.edu/ahi, the AH&I Office in 120 Wheeler Hall, or by calling (510) 642-5006.

American Cultures

The American Cultures (AC) Breadth requirement is a Berkeley campus requirement. The AC requirement was established in 1989 to introduce students to the diverse cultures of the United States through a comparative framework. Students satisfy the requirement by passing, with a grade no lower than C- or P, an AC course. Courses are offered in more than 40 departments in many different disciplines at both the lower and upper division levels. For current AC course offerings, students may search the online *Schedule of Classes* (schedule.berkeley.edu) by typing American Cultures in the "Additional Information" box. Students can also access a list of AC courses, as well as answers to frequently asked questions, on the AC web site at amercult.berkeley.edu. Students who have questions about satisfying the AC requirement should contact their staff advisers. American Cultures courses also count toward the Breadth requirement.

Senior Residence

After 90 units toward the bachelor's degree have been completed, at least 24 of the remaining units must be completed in residence in the College of Chemistry, in at least two semesters (the semester in which the 90 units are exceeded, plus at least one additional semester).

To count as a semester of residence for this requirement, a program must include at least 4 units of successfully completed courses. A summer session can be credited as a semester in residence if this minimum unit requirement is satisfied.

Juniors and seniors who participate in the UC Education Abroad Program (EAP) for a *full* year may meet a modified senior residence requirement. After 60 units toward the bachelor's degree have been completed, at least 24 (excluding EAP) of the remaining units must be completed in residence in the College of Chemistry, in at least two semesters. At least 12 of the 24 units must be completed after the student has already completed 90 units. Associate dean's approval for the modified senior residence requirement must be obtained before enrollment in the Education Abroad Program.

Minimum Total Units

A student must successfully complete at least 120 semester units in order to graduate.

Grades

A student must earn at least a C average (2.0 grade point average) in all courses undertaken at UC, including those from UC Summer Sessions, UC Education Abroad Program, and UC Berkeley Washington Program, as well as XB courses from University Extension.

Scholarship Requirements

Academic Probation

Students in the College of Chemistry are placed on academic probation and are subject to dismissal from the University:

- if at the end of any term they failed to attain at least a C average (2.0) for the courses in which they were enrolled for that term; or
- if at the end of any term they have failed to maintain at least a C average (2.0) overall for all courses taken in the University.

Students on academic probation are placed under the supervision of the Associate Dean for Undergraduate Affairs. They are not allowed to take courses on a *passed/not passed* basis with the exception of recreational physical education courses and courses offered only on a *passed/not passed* basis.

Minimum Course Grade Requirements

Students in the College of Chemistry who receive a grade of D+ or lower in a chemical engineering or chemistry course for which a grade of C- or higher is required must repeat the course *at Berkeley*.

Students in the College of Chemistry must achieve:

- a grade of C- or higher in Chemistry 4A before taking Chemistry 4B;
- a grade of C- or higher in Chemistry 4B before taking more advanced courses;
- a grade of C- or higher in Chemistry 112A before taking Chemistry 112B or Biology 1A; and
- maintain a grade point average of at least 2.0 in all courses taken in the college in order to advance to and continue in the upper division.

Chemistry or chemical biology students must also achieve:

- a grade of C- or higher in Chemistry 120A or 120B if taken before 125; and
- at least a 2.0 grade point average in all upper division courses taken at the University to satisfy major requirements.

Chemical engineering students must also achieve:

- a grade of C- or higher in Chemical Engineering 140 before taking any other course in the Chemical Engineering series;
- a grade of C- or higher in Chemical Engineering 150A to be eligible to take any other course in the 150 series; and
- at least a 2.0 grade point average in all upper division courses taken at the University to satisfy major requirements.

Chemical engineering students who do not achieve a grade of C- or higher in Chemical Engineering 140 on their first attempt are advised to change to another major. If the course is not passed with a grade of C- or higher on the second attempt, continuation in the Chemical Engineering program is normally not allowed.

Minimum Progress

For undergraduates, normal progress toward a degree requires 30 units of successfully completed course work each year. The continued enrollment of a student who fails to achieve minimum academic progress shall be subject to the approval of the associate dean of the college. To achieve minimum academic progress, the student must meet two criteria:

- The student must have successfully completed a number of units no fewer than 15 times the number of semesters, less one, in which the student has been enrolled on the Berkeley campus. Summer sessions will not be counted as semesters for this purpose.
- A student's final class schedule must contain at least 13 units in any term, unless otherwise authorized by the staff adviser or the associate dean.

Academic Policies

Academic Advising and Approval of Planned Class Schedules

Members of the faculty are assigned as advisers to assist students in planning their programs and in pursuing their chosen interests. During scheduled academic advising periods, students are required to meet with their faculty advisers by appointment.

Undergraduate office staff are also assigned as advisers to assist students in choosing courses and to approve students' planned class schedules and petitions to change class schedule.

Good preparation is strongly advised before consulting with an adviser. Students should have at least a tentative idea of the courses they wish to take and should try to acquaint themselves beforehand with the course requirements listed in this announcement.

Class Schedule Requirements

Ordinarily students will not be permitted to enroll in fewer than 13 or more than 19½ units per semester. In addition, ordinarily students will not be permitted to enroll in fewer than 12 units of courses that will satisfy degree requirements per semester.

Chemical engineering freshmen and students majoring in Chemistry are required to enroll in a minimum of one chemistry course each semester. Students majoring in Chemical Engineering other than freshmen are required to enroll in a minimum of one chemical engineering course each semester.

Students are expected to complete the math and physics course requirements as soon as possible, because math and physics courses are prerequisite to other required courses. Students are encouraged to complete the English Composition and Literature requirement as soon as possible, so they have a foundation for courses that require writing skills. *Note:* English R1A or equivalent is a prerequisite for Engineering 190.

Changes to Planned Class Schedules

Students are required to consult with their staff advisers concerning proposed changes to their planned class schedules. Failure to obtain staff adviser approval for changes may result in disciplinary action. After the third Friday of classes proposed course drops and grading option changes, and after the fifth Friday of classes proposed course adds, must be submitted to staff advisers on petitions to change class schedule.

The deadline for adding courses without a fee is the third Friday after instruction begins, and the deadline for adding courses with a fee is the fifth Friday after instruction begins. The deadline for dropping courses without a fee and for dropping early-drop-deadline courses is the second Friday after instruction begins. The deadline for dropping courses with a fee, and for changing grading option from *passed/not passed* to a letter grade, is the fifth Friday after instruction begins. The deadline for changing grading option from letter grade to *passed/not passed* is the tenth Friday after instruction begins.

After the above deadlines the associate dean's approval is required for class schedule changes. Late class schedule changes will be granted only under rare and exceptional circumstances. All courses for which a drop is *processed after the fifth Friday of instruction* will appear on the student's official transcript permanently. Under no circumstances will the college waive the transcript notation.

Passed/Not Passed Courses

Students in good standing may take some courses on a *passed/not passed* basis. Such courses are acceptable only for free electives and for the following specific requirements:

- for chemistry or chemical biology majors, 15-unit Breadth requirement except for English composition; Foreign Language requirement; and
- for chemical engineering majors, all courses satisfying the Breadth requirement except for the first course in English composition (4 units).

Courses acceptable in satisfaction of the University requirements for American History and Institutions and the Berkeley campus requirement for American Cultures may also be taken on a *passed/not passed* basis.

Credit for passing *passed/not passed* courses counts toward graduation, but *passed/not passed* grades are disregarded in computing the grade point average.

Students on academic probation (below a C average, either overall or for the previous semester) are not allowed to take courses on a *passed/not passed* basis with the exception of recreational physical education courses and courses offered only on a *passed/not passed* basis.

Limit on Semesters

Students in the College of Chemistry who entered Berkeley as freshmen are allowed eight semesters to graduate. Chemistry or chemical biology majors who entered Berkeley as transfer students are allowed four semesters to graduate. Chemical engineering majors who entered Berkeley as transfer students are allowed five semesters to graduate. Please note that summer sessions are excluded when determining the limit on semesters. Students who wish to delay graduation to complete a minor, a double major, or simultaneous degrees must request approval for delay of graduation *before* what would normally be their final two semesters. The College of Chemistry does not have a rule regarding maximum units that a student can accumulate.

Additional Transfer Credit

Students in the College of Chemistry are subject to the following restrictions concerning additional transfer credit:

- *Before* enrolling in a course at another institution which could satisfy a required chemical engineering, chemistry, English, math, or physics course, students are required to request approval from their staff advisers.
- Students planning to enroll concurrently at Berkeley and another institution are required to request approval from the associate dean before the beginning of the semester. Approval of concurrent enrollment is rarely granted.

Withdrawal and Readmission

Students who find it necessary to discontinue attending classes during a semester must formally request withdrawal from the University by contacting their staff advisers. For students who withdraw from a semester after the eighth week of classes, a "semester-out" policy is in effect. This means that the student is required to "stay out" the following semester in order to resolve the problems that contributed to the withdrawal.

Note: Fee refunds are based on the date on which the adviser processes the withdrawal, not when the student stopped attending classes. Consult the online *Schedule of Classes* for the fee refund schedule.

After withdrawing or being absent for one or more semesters, the student may apply for readmission by submitting an Application for Readmission to the staff adviser. Readmission is not guaranteed and is based upon the student's academic record at the time of withdrawal, upon any course work taken during the absence from Berkeley, and upon the resolution of the problems that contributed to the withdrawal. If the student attended other institutions during the absence, the student must present official transcripts from each institution before readmission will be considered.

Change of College

Students from other colleges or schools (Letters and Science, Engineering, Natural Resources, etc.) at Berkeley may apply for a change of college to the College of Chemistry. Petitions for change of college to the College of Chemistry are considered on a case-by-case basis and are accepted year-round. Students should be in good academic standing (i.e., not on probation) and should be taking appropriate courses for their intended majors.

Students in the College of Chemistry who want to change to another college or school at Berkeley are required to notify their staff advisers.

Double Majors and Simultaneous Degrees

Students who wish to pursue double majors or simultaneous degrees:

- must submit the appropriate paperwork *before* what would normally be their final two semesters;
- may use no more than two upper division courses to satisfy requirements of both majors; and
- must have a grade point average of at least 2.5.

Please note: Having double majors or simultaneous degrees will not necessarily improve students' chances for admission to graduate programs or increase opportunities within their chosen careers.

Note: Double majors in Chemistry and Chemical Biology are not permitted.

Minors

For students in the College of Chemistry who plan to pursue a minor, at least four courses taken for the minor must not be included in the student's major program. This rule applies to students who matriculate to Berkeley in fall 2008 or later.

Academic Opportunities

Undergraduate Research

Students have the opportunity to earn units while participating in research by enrolling in Chemistry or Chemical Engineering 196, Special Laboratory Study, or H194, Research for Advanced Undergraduates. Junior or senior students who have at least a 3.4 overall grade point average at Berkeley may take Chemistry or Chemical Engineering H194. Students contemplating graduate study in chemistry or chemical engineering are particularly urged to include 196 or H194 in their course programs. Plans for this should be initiated in the junior year with a view to including the course in both semesters of the senior year.

In chemistry the student may undertake original research in several fields including physical-chemical studies of substances at very high and very low temperatures, rates and mechanism of reactions (both organic and inorganic), spectroscopic investigations in all areas, magnetic and electric properties of matter, quantum chemistry, radiochemical tracer techniques in various branches of chemistry, nuclear reactions and nuclear spectroscopy, and structures of natural products of biological interest.

In chemical engineering the student may engage in research under the direction of a faculty member. Research fields currently under investigation include phase equilibria, polymers, catalysis and reactor design, electrochemical processes, interfacial phenomena, heat and mass transfer, dynamics and control, optimization, hydrodynamics, biochemical processes, and many others.

Honors at Graduation

To be eligible for honors in general scholarship at graduation, a student must:

- complete a minimum of 50 semester units at the University of California, of which a minimum of 43 units must be undertaken for a letter grade;
- complete a minimum of 30 units at Berkeley; and
- achieve a UC Berkeley grade point average that ranks the student in the College of Chemistry's top three percent for highest honors, the next seven percent for high honors, and the next 10 percent for honors.

College of Chemistry Scholars Program

Recruitment and Outreach
The objective of the College of Chemistry Scholars Program Recruitment and Outreach component is to increase the number of students from underrepresented groups at Berkeley who enroll and graduate with Bachelor's degrees in chemistry, chemical biology, or chemical engineering. The recruitment and outreach component includes early outreach to K-12 schools. For information on the recruitment and outreach component, please contact the College of Chemistry, University of California, Berkeley, 420 Latimer Hall #1460, Berkeley, CA 94720-1460, or call (510) 642-3451.

Retention
The College of Chemistry Scholars Program Retention component, in conjunction with the Recruitment and Outreach component, is designed to increase the number of students from underrepresented groups at Berkeley, to improve retention rates of these students, and to prepare them for professional careers and graduate school in science fields. Toward this end, the college offers intensive workshop courses to supplement Chemistry 1A, 4A-4B, and 112A-112B. Students in the College of Chemistry Scholars Program are provided with academic and personal support and increased opportunities to meet faculty, to perform research, and to obtain summer internships and employment. For information on the retention component, please contact the College of Chemistry, University of California, Berkeley, 420 Latimer Hall #1460, Berkeley, CA 94720-1460, or call (510) 643-1745.

Graduate Programs

Department of Chemical Engineering
University of California, Berkeley
201 Gilman Hall #1462
Berkeley, CA 94720-1462
(510) 642-2291
cheme.berkeley.edu

Department of Chemistry
University of California, Berkeley
419 Latimer Hall #1460
Berkeley, CA 94720-1460
(510) 642-5882
chem.berkeley.edu

Admission

Both departments have detailed information describing their graduate programs at cheme.berkeley.edu and chem.berkeley.edu, respectively. Application forms and deadlines for admission and financial support are also available there. Completed forms should be returned directly to that department. All applicants are automatically evaluated for their qualifications as graduate student instructors and research assistants; no special forms for these positions are required.

Early application is strongly recommended for those seeking fellowships or assistantships.

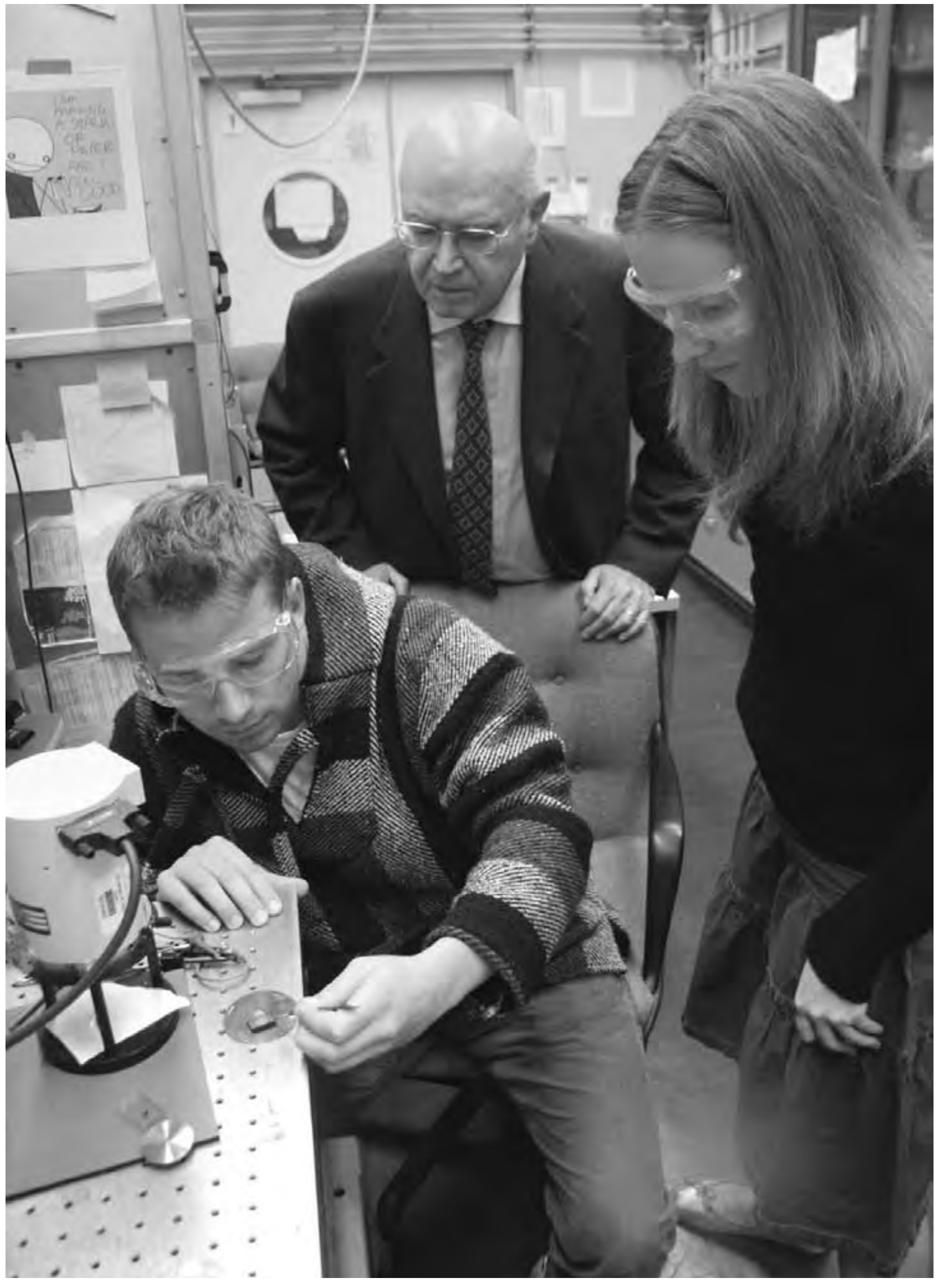
Please note: The Graduate Record Examination is required of all applicants.

Assistantships and Fellowships

Graduate students in chemistry at Berkeley are supported for five years. During the first three years of graduate work, most students serve as graduate student instructors for one semester and as research assistants for the remainder of the year. After the third year students are supported primarily as research assistants.

In chemical engineering, students are normally appointed to graduate student instructor positions in only one semester of an academic year. Two semesters of appointment during Ph.D. studies are required, but the appointments are distributed over the first three years. Support of students is accomplished primarily through research assistantships and is available throughout the academic year and the summer.

Graduate student instructors are regarded as full-time students. Appointments require that the students divide their time between teaching duties and their own studies.



Research assistantships for graduate students in chemistry and chemical engineering are available on many special projects, including work in the Lawrence Berkeley National Laboratory. The scholastic requirements and remuneration for such assignments are the same as those for graduate student instructor appointments. Research assistant appointments are restricted to work that is directly relevant to the student's thesis research.

Fellowships reserved for graduate students in chemistry and chemical engineering have been established by several individual and corporate donors. Prospective graduate students are also encouraged to apply for nationally available fellowships, such as those offered by the National Science Foundation.

Department of Chemical Engineering

Chemical Engineering as a Profession

Chemical engineers contribute to a broad spectrum of technical activity reaching into practically every aspect of advanced technology. This breadth of activity is illustrated by a vast range of representative endeavors: fibers and films from man-made polymers; new liquid and gaseous fuels from coal; drug and antibiotic manufacture; food preservation; unique chemicals from enzymatic reactions; thin-film processes for electronic devices; new catalysts for energy needs; removal of air and water pollutants; nuclear fuel reprocessing; solar energy system development; new battery and fuel-cell systems — and countless others.

The chemical engineers' interest in these fields is in the invention and development of materials and processes useful to society. Historically, their work has been pivotal and indispensable. The unique element of their involvement in these fields is their capability to plan and implement chemical transformations and separations. In the complex processes of both nature and industry, chemical and physical phenomena are nearly always closely associated. It is the interaction between such phenomena that the chemical engineer seeks to master. In addition, the discipline of economics enters as a third dimension in every technological endeavor.

Chemical engineers' occupations span the full range of activity from fundamental research to process development, process operations, marketing, industrial and government liaison, and company management. Contributions to nearly all of these activities are made by graduates of the four-year Bachelor of Science program. A master's or doctor's degree is needed for research and teaching. In industrial enterprises technical work is often conducted by teams, and the young engineer may expect to become an active member of such a team from the start. Teamwork fosters rapid professional development in mastering complex situations, contributing ideas, and communicating with persons in diverse technical and nontechnical areas. In some organizations, an engineer may follow a project from its laboratory developmental stages through pilot plant proving, commercial plant design, plant startup, and plant operations.

Capable engineers may expect to be promoted to a chain of supervisory positions within five to 10 years after having begun their industrial careers. These assignments may lead to positions as task-force director, laboratory director, plant manager, division director, or company president. Some engineers with an entrepreneur's bent will form their own companies to manufacture, for example, a novel instrument, to develop and market a new process, or to capitalize on their knowledge in the capacity of a consultant.

Because of their breadth of function and breadth of field, chemical engineers at all degree levels have been actively sought by industrial enterprises, governmental agencies, and academic institutions, and the remuneration offered to starting engineers has consistently ranked among the highest offered university graduates.

The Department of Chemical Engineering

Knowledge of the fundamentals of chemical engineering and creativity in their application constitute essential equipment for meeting the unseen challenges of engineering 10, 20, or 30 years ahead. What are the fundamentals? In the early years: chemistry, physics, biology, mathematics, and English. Later: fluid flow, heat transfer, mass transfer, separations, engineering thermodynamics, materials engineering, chemical reaction engineering, process design and control, and technical communication. In advanced and graduate programs: application areas such as electrochemical engineering, polymers and soft materials, microelectronics processing and MEMS, catalysis, biochemical and biomedical engineering, and many others.

The study is rigorous; grasping the fundamentals and mastering their application do not come spontaneously. In advanced and graduate programs, individual projects carried out in close collaboration with a faculty member provide the primary mode of learning.

The department is richly endowed with human and material resources to accomplish its educational objectives. Eighteen full-time faculty members with expertise spanning nearly every major area of the field conduct courses from the sophomore level through the graduate level. All are actively engaged in research. A number of special lecturers add further breadth. Laboratories abound; for undergraduates, laboratory courses are provided in general chemical engineering and process control (required of all students), applied kinetics, polymers, and biochemical engineering. The graduate research laboratories, accommodating a graduate student body of about 100, are equipped for biochemical engineering, bioengineering, and biomedical engineering; phase equilibria; quantum and statistical mechanics; electrochemical engineering; catalysis and reaction engineering; rheology; polymer chemistry and physics; surface and colloid science; MEMS; materials chemistry, engineering, and synthesis; and plasma processing.

Statement of Intent to Accommodate Students with Disabilities. As is noted in the "Nondiscrimination Statement" at the back of this announcement, the Department of Chemical Engineering does not discriminate negatively on the basis of race, color, national origin, sex, handicap or age in any aspect of its program. In particular, the College of Chemistry assures graduate students with physical disabilities that their needs will be accommodated in the design, construction and operation of the equipment used to carry out their research projects. This policy includes any necessary modification of existing equipment and auxiliary laboratory facilities required to carry out the project.

The Chemical Engineering Undergraduate Curriculum. The mission of the Department of Chemical Engineering is to educate men and women for careers of leadership and innovation in engineering and related fields; to expand the base of engineering knowledge through original research, developing technology to serve the needs of society; and to benefit the public through service to industry, government, and the engineering profession. Fulfillment of this mission is achieved in part by the department's Accreditation Board for Engineering and Technology (ABET) accredited undergraduate degree program in chemical engineering.

The chemical engineering undergraduate curriculum comprises both a technical curriculum and Breadth requirements. The goals of chemical engineering Breadth requirements are to learn the arts of writing clearly and persuasively, to read carefully and evaluate evidence effectively, and to be aware of humanity in historical and social contexts.

The technical curriculum in chemical engineering seeks to provide students with a broad education emphasizing an excellent foundation in scientific and engineering fundamentals.

The objectives of the undergraduate program are to produce graduates who:

- understand the fundamental mathematics and sciences that provide the foundation for engineering applications and technological innovation;
- apply scientific and engineering principles to analyze, design, and synthesize chemical and physical systems of importance to society;
- are intellectual leaders, capable of functioning creatively in an independent work environment and as a member of a team;

- use appropriate analytic, numerical, and experimental tools to investigate chemical and physical systems;
- integrate modern information technology and computational and engineering tools into engineering practice;
- communicate effectively by oral, written, and graphical means;
- are both competent and confident in interpreting the results of engineering investigations;
- appreciate the importance of and opportunities for lifelong learning;
- recognize the broad social context, both historical and contemporary, within which engineering is practiced; and
- understand the ethical, professional, and citizenship responsibilities of engineering practice.

Undergraduate Programs

The Bachelor of Science Degree in Chemical Engineering is designed to equip the student for professional work in development, design, and operation of chemical products and processes. It prepares the student for employment in such industries as chemical, petroleum, electrochemical, biochemical, semiconductor, nuclear, aerospace, plastics, food processing, environmental control, or related industries. Students with high scholastic attainment are well prepared to enter graduate programs leading to advanced degrees in chemical engineering or in related professional, scientific, and engineering fields.

To graduate with a B.S. degree, the student must have:

- fulfilled the degree requirements and scholarship requirements as specified on pages 8 and 9 of this announcement;
- satisfactorily completed a *minimum of 120 units;*
- satisfactorily completed a minimum of 45 engineering units excluding both Engineering 7 and 190; and
- satisfied the requirements listed in the lower division program, upper division program, and additional electives and concentrations sections that follow.

The undergraduate course of study is accredited by the Accreditation Board for Engineering and Technology.

Lower Division Program

During the freshman and sophomore years it is important for the student to complete the following requirements:

Reading and Composition. The student must demonstrate reasonable proficiency in English composition by satisfactory completion of one of the courses listed in this announcement under the “College of Chemistry Breadth Requirement Course List: Group I (Reading and Composition).” This course may *not* be taken on a P/NP basis. It is a prerequisite for Engineering 190.

Students who plan to take English at another institution during a summer term or before readmission to Berkeley should check with the College of Chemistry Undergraduate Majors Office for verification of course acceptance. After admission to Berkeley, credit for English at another institution will not be granted if the Entry-Level Writing requirement has not yet been satisfied.

[1]**19-Unit Breadth Requirement.** The student must include one course in English composition (see Reading and Composition above) and additional courses in humanities, social sciences, or composition. Refer to the “College of Chemistry Breadth Requirement Course List” in the “General Information” section of this publication. As part of the 19 units, students are required to complete two courses, at least one being upper division, in the same or a very closely allied humanities or social science department. Advanced Placement credit may be linked with an upper division course to satisfy this requirement.

Freshman Seminar. Chemical Engineering C96 introduces entering freshmen to research and study in the College of Chemistry. Students who enter the College of Chemistry as freshmen are required to take the course during their first fall semester at Berkeley. Enrollment in the course is restricted to students who recently entered the College of Chemistry.

Chemistry. 4A, 4B, 112A. This program should start in the first semester of the freshman year. (*Note:* A grade of C- or better is required in Chemistry 4A before taking 4B and also in 4B before taking more advanced courses. Students must receive a grade of C- or better in 112A before taking Biology 1A or Chemistry 112B.)

Chemical Engineering. 140, 141, 150A. The student *must* complete 140 with a grade of C- or better before enrolling in *any other course* in Chemical Engineering. A grade of C- or better in 150A is required before any additional course in the 150 series may be taken.

Engineering. 7. Engineering 7 must be taken before, or concurrently with, Chemical Engineering 141 and before 150B.

Mathematics. 1A, 1B, 53, 54. This program should start in the first semester of the freshman year.

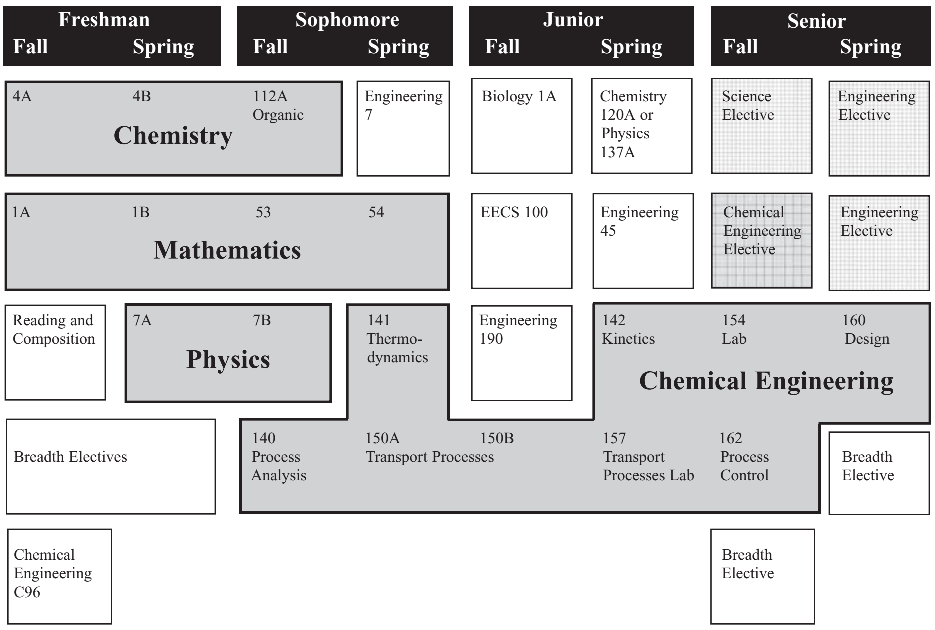
Physics. 7A, 7B. This program should start in the second semester of the freshman year. (*Note:* Students who plan to take Physics 137A in lieu of Chemistry 120A must also take Physics 7C.)

The following program is suggested for the first two years. *Note:* Students must achieve a 2.0 grade point average in College of Chemistry courses to continue in the program. Students wishing to take a lighter load during their first two years may take courses such as Math 53 or 54, Physics 7B, and breadth electives in the summer session.

Suggested Lower Division Program for Chemical Engineering

		Units
Freshman Year	*Fall*	*Spring*
Chemistry 4A-4B	4	4
Chemical Engineering C96	1	-
Mathematics 1A-1B	4	4
Physics 7A	-	4
English Composition	4	-
[1]Breadth Elective	4	4
[2]Total	**17**	**16**
Sophomore Year		
Chemistry 112A	5	-
Chemical Engineering 140, 141	4	3
Chemical Engineering 150A	-	4
Mathematics 53-54	4	4
Physics 7B	4	-
Engineering 7	-	4
Total	**17**	**15**

Representative Undergraduate Chemical Engineering Program



Upper Division Program

During their junior and senior years, students must complete the following course requirements:

[3]**Biology.** 1A (lecture only). (*Note:* Biotechnology-concentration students are required to take Molecular and Cell Biology 102 in place of Biology 1A.)

Chemistry. 120A, or Physics 137A.

Chemical Engineering. 142, 150B, 154, 157, 160, 162.

Engineering. 45, 190.

Note: Students are required to take a language placement test designed to gauge their language proficiency before enrolling in Engineering 190. Students who do not place into Engineering 190 are required to complete 140 before taking 190. Since one of the prerequisites for Chemical Engineering 154 is Engineering 190, students should plan to take the 190 placement test well enough in advance to take 190 (and possibly also 140) before taking Chemical Engineering 154. More information may be found online at coe.berkeley.edu/ids/techcomm.

Electrical Engineering and Computer Sciences. 100.

Additional Electives and Concentrations

In addition to the requirements listed above, students must complete the requirements for either an *open elective program* consisting of a series of science and engineering electives from a broad range of courses or a *concentration* with the concentration noted on the student's official transcript after the B.S. degree is conferred.

Note: A course used toward satisfaction of the open elective program or a concentration cannot also be used toward satisfaction of another college or major requirement. A maximum of six units of research can be applied toward electives.

Open Elective Program

Students who do not choose a concentration must complete the following requirements for the open elective program:

- 3 units of science elective selected from the "Suggested Physical and Biological Science Courses" section of this announcement (see "Table of Contents") in consultation with the student's faculty adviser;
- 3 units of chemical engineering elective (Chemical Engineering 196 may not be used as a Chemical Engineering elective); and
- 6 units of engineering electives chosen from the engineering and chemical engineering courses listed in the "Suggested Engineering Electives" section of this announcement (see "Table of Contents") or approved by the student's faculty adviser.

Concentrations

The concentrations are biotechnology, chemical processing, environmental technology, materials science and technology, and applied physical science. Students who plan to declare a concentration must do so no later than the end of their junior year. Double concentrations are not permitted.

Biotechnology
- Chemistry 112B or Molecular and Cell Biology C112
- Chemical Engineering 170A, 170B, and C170L

[3]*Note:* Biotechnology-concentration students are required to take Molecular and Cell Biology 102 in place of Biology 1A.

[4]**Chemical Processing**
- Chemistry 104A or 112B
- 6 units of chemical engineering electives chosen from the following: 170A, 170B, C170L, 171, 176, C178, 179, H194 (up to 3 units)
- 3 units of engineering selected from the following: Civil Engineering 111, 114, 130, 173, Materials Science and Engineering 111, 112, C113, C118, 120, 121, 122, 123, Mechanical Engineering 140, 151

Environmental Technology
- Chemistry 112B or 104A
- Chemical Engineering 170A
- 6 units chosen from the following: Chemical Engineering 176, Civil Engineering 108, 109, 111, 113N, C116, 173, Mechanical Engineering 140

[4,5]**Materials Science and Technology**
- one of Chemistry 104A, 108, or 112B
- 3 units of chemical engineering elective selected from the following: 176, C178, 179
- 6 units chosen from the following: Civil Engineering 130, Electrical Engineering and Computer Sciences 130, 143, Materials Science and Engineering 102, 103, 111, 112, 120, 121, 122, 123, 125, Mechanical Engineering 122, 127

Applied Physical Science
- 6 units of chemistry or physics approved by the student's faculty adviser
- 3 units of chemical engineering elective (Chemical Engineering 196 may not be used as a Chemical Engineering elective.)
- 3 units of engineering selected from the "Suggested Engineering Electives" section of this announcement (see "Table of Contents")

[1]May be taken on P/NP basis.

[2]For the first semester, students may consider taking one fewer course.

[3]Biotechnology-concentration students who do not have a background substantially equivalent to Biology 1A may want to take Biology 1A as a prerequisite to Molecular and Cell Biology 102.

[4]Students who have a good grasp of the material in Physics 7A may take Civil Engineering 130 without the prerequisite of Engineering 36.

[5]Students may take Mechanical Engineering 122 without the prerequisites of Civil Engineering 130 and Mechanical Engineering 102A.

Representative Chemical Engineering Program for Transfer Students

Junior Fall	Junior Spring	Senior Fall	Senior Spring	Senior Fall
Chemistry 112A	Biology 1A	Chemistry 120A or Physics 137A	Science Elective	Engineering Elective
Engineering 45	Engineering 190	EECS 100	Chemical Engineering Elective	Engineering Elective
Chemical Engineering: 140 Process Analysis	Chemical Engineering: 141 Thermo-dynamics	Chemical Engineering: 157 Transport Processes Lab	Chemical Engineering: 142 Kinetics	Chemical Engineering: 154 Lab
Breadth Elective	Chemical Engineering: 150A Transport Processes	Chemical Engineering: 150B	Chemical Engineering: 162 Process Control	Chemical Engineering: 160 Design
		Breadth Elective		

Representative Chemical Engineering Program for Transfer Students

Transfer students normally matriculate in the fall of their junior year having completed courses equivalent to Chemistry 1A, 1B; Math 1A, 1B, 53, 54; Physics 7A, 7B; Engineering 7 (or other acceptable computer programming course); English R1A; and most of the Breadth requirement. For such students, major requirements to be taken after transfer to Berkeley appear in the above chart.

Joint Major Programs

Joint major programs with the College of Engineering are offered in Chemical Engineering and Materials Science and Engineering, and Chemical Engineering and Nuclear Engineering.

General Requirements

The programs of study shown on the following pages contain comparable proportions of course work in Materials Science and Engineering or Nuclear Engineering and in Chemical Engineering. Students will enroll concurrently in both the College of Engineering and the College of Chemistry, but their college of residence will be Chemistry. Continuing students may petition for change to a joint major program after they attain sophomore standing. Since students in these joint majors are not required to complete all of the requirements for both single majors, students receive one diploma upon completion of the joint majors.

Chemical Engineering and Materials Science and Engineering
Many of the engineering problems facing the nation in the next decades will require solution by engineers who have training in both chemical process engineering and materials engineering. Three typical examples are coal gasification and liquefaction, extraction of metals from low-grade ores and wastes, and environmental control of metallurgical processes.

Chemical Engineering and Nuclear Engineering
The areas of nuclear technology that depend heavily upon chemical engineering training include: isotope separation, fuel reprocessing, waste management, feed material preparation, fuel chemistry, effluent control, fusion reactor fuel processing, and new reactor types.

*Joint Major Program in Chemical Engineering and Materials Science and Engineering — 128 Units

Freshman Year	*Fall*	*Spring*
Math 1A, 1B, Calculus	4	4
Chemistry 4A, 4B (or 1A, 1B), General Chemistry	4	4
Physics 7A, Physics for Scientists and Engineers	-	4
[1]English R1A or Equivalent	4	-
[1]Breadth Electives	3	3
Total	**15**	**15**
Sophomore Year		
Math 53, 54, Multivariable Calculus; Linear Algebra and Differential Equations	4	4
Physics 7B, 7C, Physics for Scientists and Engineers	4	4
Chemistry 112A, Organic Chemistry	5	-
Chem Eng 140, Introduction to Chemical Process Analysis	4	-
Chem Eng 141, Chemical Engineering Thermodynamics	-	3
Chem Eng 150A, Transport Processes	-	4
Eng 7, Introduction to Computer Programming for Scientists and Engineers	-	4
Total	**17**	**19**
Junior Year		
EECS 100, Electronic Techniques for Engineering	4	-
Eng 45, Properties of Materials	3	-
[2]Mat Sci 102, Bonding, Crystallography, and Crystal Defects	3	-
Mat Sci 103, Phase Transformations and Kinetics	-	3
[3]Mat Sci elective	-	3
Chemistry 120A, Physical Chemistry	3	-
Chem Eng 142, Chemical Kinetics and Reaction Eng	-	3
Chem Eng 150B, Transport and Separation Processes	4	-
Eng 190, Technical Communication	-	3
[1]Breadth Elective	-	3
Total	**17**	**15**
Senior Year		
[3]Mat Sci elective	4	-
Mat Sci 120, Materials Production	3	-
Mat Sci 130, Experimental Materials Science	3	-
Chem Eng 154, Chemical Engineering Laboratory	3	-
Chem Eng 157, Transport Processes Laboratory	-	3
Chem Eng 160, Chemical Process Design	-	4
Chem Eng 162, Dynamics and Control of Chemical Processes	-	4
[1]Breadth Electives	3	3
Total	**16**	**14**

*Students must complete a minimum of 23 upper division units in the College of Engineering.

[1]Breadth electives must include 19 units of humanities (including English composition) and social sciences which satisfy the requirements of both the College of Chemistry and the College of Engineering. For information on the College of Engineering humanities and social studies requirement, refer to coe.berkeley.edu/hssreq.pdf for details or go to 308 McLaughlin Hall for a handout.

[2]Permission from the Mat Sci 102 instructor is required to take Eng 45 concurrently.

[3]Mat Sci electives must include one course from Mat Sci 104, 111, 112, C113, 117, C118, or 125; and one course from Mat Sci 121, 122, 123, or 125. The joint major program must include a minimum of 23 upper division technical units in the College of Engineering. To satisfy the 23-unit requirement, either one of the Mat Sci electives must be four units or an additional course must be taken. Technical electives cannot include Eng 124, 195; or Bioeng 100.

*†Joint Major Program in Chemical Engineering and Nuclear Engineering — 125-126 Units

Freshman Year	*Fall*	*Spring*
Math 1A, 1B, Calculus	4	4
Chemistry 4A, 4B (or 1A, 1B), General Chemistry	4	4
Physics 7A, Physics for Scientists and Engineers	-	4
Eng 7, Introduction to Computer Programming for Scientists and Engineers	-	4
[1]English R1A or Equivalent	4	-
[1]Breadth Elective	3	-
Total	**15**	**16**
Sophomore Year		
Math 53, 54, Multivariable Calculus; Linear Algebra and Differential Equations	4	4
Physics 7B, 7C, Physics for Scientists and Engineers	4	4
Chem Eng 140, Introduction to Chemical Process Analysis	4	-
Chem Eng 141, Chemical Engineering Thermodynamics	-	3
Chem Eng 150A, Transport Processes	-	4
EECS 100, Electronic Techniques for Engineering	4	-
Total	**16**	**15**
Junior Year		
Eng 45, Properties of Materials	3	-
Eng 117, Methods of Engineering Analysis 3	-	
Nuc Eng 101, Nuclear Reactions and Radiation	4	-
Nuc Eng 104, Radiation Detection and Nuclear Instrumentation Lab	-	3
Nuc Eng 150, Nuclear Reactor Theory	-	3
Chem Eng 142, Chemical Kinetics and Reaction Engineering	-	3
Chem Eng 150B, Transport and Separation Processes	4	-
Eng 190, Technical Communication	3	-
[1]Breadth Electives	-	6
Total	**17**	**15**
Senior Year		
[4]Nuc Eng electives	9	-
Chemistry 120A, Physical Chemistry	3	-
Chem Eng 154, Chemical Engineering Laboratory	3	-
Chem Eng 157, Transport Processes Laboratory	-	3
Chem Eng 160, Chemical Process Design or Nuc Eng 170A, Nuclear Design	-	3-4
Chem Eng 162, Dynamics and Control of Chemical Processes	-	4
[1]Breadth Electives	-	6
Total	**15**	**16-17**

[4]Nuc Eng electives: Students select nine units of upper division Nuc Eng courses, including at least two courses selected from Nuc Eng 120, 124, or 161.

†Ethics requirement: Students must take one course with ethics content. This may be fulfilled within the humanities and social studies requirement by taking one of the following courses: Bioeng 100; Eng 124, 195; Anthro 156B; ESPM 161, 162; Philosophy 2, 104, 105, 107; Political Science 108A; Public Policy 170, 172; Public Health 115; Sociology 116; Legal Studies 19AC, 100A.

Chemical Engineering Minor

A minor in chemical engineering will be awarded to students who have successfully completed five upper division chemical engineering courses as follows: 140, 141, and 150A plus any two courses selected from 142, 150B, 157, 162, 170A, 170B, 171, 176, C178, or 179. Students who have completed courses in other departments at Berkeley that are essentially equivalent to 141 and 150A can substitute other courses from the above list. At least three of the five courses taken for the minor must be taken at Berkeley. All courses taken for the minor must be taken for a letter grade. Students must achieve at least a 2.0 grade point average in the courses taken for the minor for both of the following: (1) courses taken at Berkeley and (2) courses taken at another institution and accepted by the College of Chemistry as equivalent to courses at Berkeley. For the minor to be awarded, the student must submit a notification of completion of the minor at 420 Latimer Hall.

Note: Students must consult with their colleges/schools for information on rules regarding overlap of courses between their majors and minors.

Suggested Physical and Biological Science Courses

The following departments offer courses that satisfy the science elective for the open elective program. Students should consult with their faculty advisers when selecting courses to satisfy the science elective.

Anthropology 1, 108, 109, C131, 132, 133, 134, 135

Astronomy 3, 4, 7A, 7B, 9, 10, C10, C12, C149, 169

Biology 1B

Chemistry 103, 104A, 104B, 105, 108, 112B, 113, 115, 120B, 122, 125, C130, 135, 143, 146, C150, 192, H194, 196

Cognitive Science C102, C110, C126, C127

Earth and Planetary Science 3, 8, C12, 20, 50, 60, 80, 100A, 103, 105, 106, 108, 117, 121, C129, 130, C141, C146, C149, C171, 181, 182, 185

Energy and Resources Group 102, 120

Environmental Science, Policy, and Management 2, 4, 10, 11, C12, 20, 40, 42, 44, 100, 102A, 102B, 102C, C103, 105A, 105C, 106, 108A, 108B, 109, 110, 112, 113, 114, 115B, 117, 118, 119, 120, 124, 126, 127, C129, C130, 131, 134, 135, C138, 140, 142, 144, 145, 146, 148, 172, 180, 181, 185, 186

Environmental Sciences 10, 125

Geography 1, 40, C136, 140A, C141, 143, 144, C145, 148, 171, 185

Integrative Biology 15, 31, 32, 33, 34, 41, 60, C82, 100A, 100B, C101, C101L, 102, 102L, 103, 103L, 104, 104L, 106, 106A, C107, C107L, 108, 117, 117L, 123A, 124, 130, 131, 135, 135L, 137, C143A, C143B, C144, C147, 148, 149, 150, 151, 152, 153, 154, C156, 157L, 161, 162, 165, 168, 168L, 174, 174L, 181, 182, 182L, 183

Molecular and Cell Biology 32, 41, 50, 61, 64, C100A, 102, C103, 111, C112, 113, C114, 115, C116, 130, 132, 135A, 135E, 135K, C135V, 136, 140, C142, C148, 150, C160, 163, 166

Nutritional Science and Toxicology 10, 106, 107, 110, C112, 113, C119, 150, 160

Physics 7C, 21, 105, 110A, 110B, 112, 129, 132, 137A, 137B, 138, 141A, 177

Plant and Microbial Biology 10, 40, C102, C102L, C103, C107, C107L, 110, 110L, C112, C114, 120, 120L, 135, C148, 150, 160, 170, 180

Psychology 110, 111, 112, C113, 114, 115A, C115B, C115C, C116, 117, 119, 122, C126, C127, C129

Public Health C102, 150C, 162A, C170B, 171C, 172, C172

Suggested Engineering Electives

The engineering elective courses required for the open elective program or the applied physical science concentration must be selected from the list below, or from among the engineering courses listed under the concentrations (see page 15).

Bioengineering 100

Civil and Environmental Engineering 114, 130, 131, 175, 176, 193

Chemical Engineering 170A, 170B, C170L, 171, 176, C178, 179, H194, 196

Electrical Engineering and Computer Sciences 105, 130, 131, 143, 145A

Engineering 102, 117, 120

Industrial Engineering and Operations Research 160, 162

Materials Science and Engineering 112, C113, 120, 121, 122, 123, 126, 151

Mechanical Engineering 110, 127, 140, 142, 146, 151, 166, 185

Nuclear Engineering 101, 124

Graduate Programs

Master's Degree

The master's degree program places equal emphasis on advanced course work and on research. A research project and thesis are required of all candidates in order to provide each student with the opportunity for growth and with maturity in independent professional activity.

The Graduate Division requires completion of 20 semester units. At least 14 units must be in letter-graded courses, which must include a minimum of nine units in graduate-level (200 series) chemical engineering courses; the remaining units may be chosen from the wide variety of courses available in the science, engineering, and business departments of the campus. Unit credit is also given for graduate research, department seminars, and special studies.

The specific courses taken in the master's program are selected in consultations between students and their academic advisers. Students are encouraged to broaden their knowledge and to pursue particular specialized interests through their choices of courses.

Selection of a research topic is made early in the first semester after students have discussed prospective research projects with faculty members whose research is of special interest to them. Many students complete their programs in 20 months; the average time in residence is 28 months.

The Product Development Program

In fall 2006, the Department of Chemical Engineering initiated an innovative Product Development Program (PDP). The PDP degree program aims to train graduates of chemical engineering and related disciplines in the complex process of transforming technical innovations into commercially successful products. In one calendar year, PDP graduates will gain exposure to real-world product development practices in a range of chemical process-intensive industries including biotechnology, microelectronics, nanoscience, and consumer products. The PDP does not require a research thesis, but students will be challenged by extensive course work and field study assignments.

By combining elements of advanced technical knowledge with focused business-related training, the PDP aims to fill a specific niche in engineering graduate education.

PDP students are required to complete a minimum of 24 semester units. At least 18 units must be in letter-graded courses and must include a minimum of 12 units in graduate-level (200 series) courses. At least 12 of the 24 units must come from graduate courses from within the chemical engineering department and can include units from department seminars and field-study projects. Specific course work to pursue an industry specialization will vary on the basis of the individual student's interests and the availability of course offerings in a given year.

Each student who successfully completes the program's graduation requirements will be awarded a Master of Science Degree in Chemical Engineering with an emphasis on product development. For more information, go to cheme.berkeley.edu/PDP/overview.html.

Doctor of Philosophy Degree

The Ph.D. program is designed to enlarge the body of knowledge of the student and, more importantly, to discover and develop talent for original, productive, and creative work in chemical engineering.

Breadth of knowledge and professional training are achieved through advanced course work. The course requirement is 30 letter-graded semester units derived as follow:

- 12 units from a required core of four chemical engineering courses in the areas of mathematics, thermodynamics, reaction engineering, and transport phenomena;
- 6 units from departmental graduate-level courses and from Chemical Engineering 170A, 170B, 178, and 179 (at least one graduate course is expected);
- a 9-unit technical sequence from upper division and graduate courses in other departments; and
- 3 units in either the departmental or technical sequence category.

In addition to these 30 units, the department recognizes that practicing chemical engineers draw increasingly on information from other disciplines. Students are strongly encouraged to pursue additional courses of specific relevance to their thesis research and to explore other areas of technical, professional, or personal interests.

To develop the creative talents of students, a paramount emphasis in the Ph.D. program is placed on intensive research, a project on which students work closely with members of the faculty. Students are expected to consult extensively with faculty members to choose the research project early in their first semester. Students begin their research at that time.

Two departmental examinations are required in the course of the degree. The first, an oral preliminary examination, is held at the beginning of the second semester to ensure adequate knowledge of fundamental graduate and undergraduate course material. The results of this examination, performance in course work, and a statement from the student's research director(s) are used by a committee of the faculty to evaluate the student's progress toward the Ph.D.

The second examination, the oral qualifying examination, is normally taken early in the fifth semester in residence. The examination is a formal presentation of the student's research program, including review of the most relevant literature, research accomplishments to date, and a future plan. Before the oral presentation, the student must submit a 25-page summary of this material. Students are expected to demonstrate mastery of the fundamentals and general proficiency and significant progress in the research area. Students spend most of their time after passing the examinations on their dissertation research projects.

The department requires that each doctoral candidate assist in the instructional program of the department as a teaching assistant for two semesters. The faculty regard teaching experience as highly valuable for all graduate students, especially those who plan to teach as a career.

Near the end of their Ph.D. candidacies, students present the results of their dissertation research to the department as part of the department colloquium series or at specially scheduled meetings. An abstract of the dissertation is required.

Completion of the Ph.D. occurs with the filing of the student's dissertation. Time for completion of the degree varies from four to six years, with a median of five years.

Designated Emphasis in Nanoscale Science and Engineering

Doctoral students interested in pursuing interdisciplinary research focused on nanoscale science and engineering (NSE) may additionally join the Designated Emphasis (DE) administered by the NSE Graduate Group. The DE, like a minor, is listed on the academic transcript (e.g., Ph.D. in Chemical Engineering with Designated Emphasis in Nanoscale Science and Engineering). More information about the NSE Graduate Group and the requirements for completing the DE program is available at nano.berkeley.edu/educational/DEGradGroup.html.

Faculty Research Interests

The research interests of faculty members in the department are broad and provide graduate students an extensive choice of research areas and topics. A balanced emphasis is placed on fundamental and applied research areas, while specific topics range from experimental to theoretical. In addition to the well-established research areas of thermodynamics, fluid mechanics, separations, transport, polymer processing, and control systems, the research interests of the department also encompass the emerging areas of biotechnology, electronic materials, and interfacial phenomena.

Biochemical Engineering

Biotechnology plays an increasingly important role in the U.S. economy. Chemical engineers with expertise in biotechnology will be key players in the transformation of basic research results into manufacturing processes and/or commercial products. For example, microbial production of foodstuffs, speciality chemicals, pharmaceuticals, and wastewater treatment are industrial processes that require chemical engineering development and design approaches, but practitioners must possess a strong understanding of biochemistry and microbiology. Similarly, rational design of enzymatic processes demands an understanding of the molecular properties of enzymes and the mechanisms of enzymatic catalysis.

Specific research interests include structure-function relationships in enzyme catalysis with emphasis on enzymes employed in biotechnology (e.g., in the production of foodstuffs or specialty chemicals), enzyme immobilization and stabilization, and the cultivation of thermophilic microorganisms. Additional topics under investigation include the determination of the activities of enzymes in supercritical solvents, water-immiscible organics, and in reverse micelles and microcapsules, aqueous two-phase polymer solutions that permit the partition of proteins and cells, development of gels with reversible phase transitions for biomolecule selection, and modeling and experimental monitoring of cellular metabolism (particularly that of mammalian cells in bioreactors).

Electrochemical Science and Technology

Research in electrochemical processes builds on all of the disciplines within chemical engineering, uses a wide variety of research tools, and has a broad impact on our rapidly changing society. Environmental concerns and limited resources have renewed interest in the application of electrochemical methods to such areas as recovery of heavy metals from aqueous solutions, controlled synthesis of chemicals, corrosion, water treatment by ion exchange, electrodialysis, and energy storage and conversion.

Fundamental experimental studies to elucidate the nature of electrochemical phenomena, measurement of physical properties, and mathematical modeling play an important role in electrochemical studies. Thermodynamic data, kinetic data, and transport properties are determined for electrolytic solutions and electrochemical phase boundaries. For example, the kinetics of film formation on metal electrodes is measured in battery electrolytes. Studies of elementary electrochemical reactions are directed toward new systems that use various electrocatalysts. Electrochemical systems are also ideal for the measurement of convective diffusion rates. Battery and fuel cell operation is investigated in studies involving electrode mechanisms, electrocrystallization, film formation, and cyclic behavior.

Electronic Materials and Processing and Micro-Electro-Mechanical Systems (MEMS)

Electronic materials are used in numerous applications, including electronic, optical, mechanical, and magnetic devices for information processing, sensors, and storage. Research efforts entail a wide range of physical, chemical, and engineering issues, from atomic defects in semiconductors to thin film structure, bonding, properties, and adhesion, to composite materials for circuit boards. In addition, polymeric materials for use in advanced lithographic schemes, high dielectric strength applications, and adhesion to metal and ceramic surfaces are under investigation. The primary goal in all studies is to establish structure-property-processing relationships.

Specific projects involve experimental and theoretical studies of plasma-assisted chemical vapor deposition and etching of thin film materials, and bulk and surface characterization of structure and bonding in deposited films. In-situ spectroscopic techniques such as nuclear magnetic resonance, infrared spectroscopy, laser-induced fluorescence, and electron spin resonance are used to monitor film materials and gas-phase species during etching and deposition.

Kinetics and Reaction Engineering

The kinetics of chemical reactions occurring at the surface of solids is important in the areas of catalysis, electrochemistry, and chemical vapor deposition of thin films. A molecular-level understanding of surface reactions is being ascertained by the use of infrared spectroscopy, Raman spectroscopy, and NMR spectroscopy to characterize the structure and dynamics of adsorbed species under actual reaction conditions. Spectroscopic results are combined with steady-state and transient response measurements of reaction kinetics to obtain a detailed understanding of the relationships between surface structure, composition, and the progress of surface reactions. Theoretical methods based on quantum mechanics, statistical mechanics, and molecular dynamics are being developed to establish accurate physical descriptions of surface processes.

The mechanism and kinetics of selected organic reactions are studied over heterogeneous catalysts such as metals, metal oxides, and zeolites to establish relationships between catalyst activity and selectivity. Analogous investigations are being performed to elucidate fundamental electrochemical reactions in electrocatalytic systems, and for the purpose of understanding thin-film formation on battery electrodes and in microelectronic-device fabrication.

Polymers and Polymer Processing

Synthetic organic high-polymer materials have extensive industrial and commercial applications; thus, a broad range of research areas exists. Some of these are liquid-crystal polymers, polymer-nonpolymer interfaces, polymer thin films used as photoresist materials, electrical isolation media, microelectronic encapsulants, transport and thermodynamic properties of polymer/small molecule systems, gels for biomolecule separation, and rheology of solutions, melts, and copolymers. In each area, the research goal is to obtain a fundamental understanding of the interrelationships among the structure, properties, and processing of high-performance polymers.

Specific research efforts involve both theoretical and experimental approaches. Examples include molecular simulations of chain conformations in the bulk and at interfaces, quantum mechanical calculations of segment-surface atom interaction energies, finite-element fluid flow modeling, and lattice models for thermodynamic properties of solutions. These efforts are complemented by rheological, spectroscopic, light-scattering, dielectric, and nonlinear optical methods of polymer characterization.

Thermodynamics and Interfacial Science

Thermodynamic research seeks to secure new phase-equilibrium data, to propose and test pertinent molecular theories for representing these data, to evaluate significant theoretical parameters, to extend relations derived from the theory to the status of a predictive method, and to interface molecular-thermodynamic models and molecular simulations with computer-aided design. An important application of thermodynamic research is the development of efficient plant design, especially in separation operations.

Of current interest are equilibria in hydrocarbon fluids (especially in underground reservoirs), petrochemical mixtures, polymer solutions, including hydrophilic gels for drug delivery systems, electrode systems, and electrolyte solutions, including aqueous systems containing proteins, salts, and polymers. Interfacial properties of solid surfaces, microstructure and conjoining/disjoining forces in thin liquid films, and colloidal dispersions are also studied from a molecular perspective.

Transport Processes

Transport processes, which include fluid mechanics and selective molecular (mass) transport, are evident in research efforts in a wide variety of topical areas. For example, fluid-mechanical problems under study include single-phase, multiphase, and dispersed-phase flow through porous media, mixing and dispersive phenomena, flows with suspended particles, rheology and processing of homogeneous and filled polymeric systems, permeation through polymeric membranes, and stability of free and bounded thin-liquid films.

Mass-transport fundamentals are examined in electrochemical systems designed for convective diffusion measurements, and in novel electromachining and forming processes involving high transfer rates. In addition, attention is focused on transport in biochemical systems and on ionic and sorptive diffusion in gels and porous catalysts. Finally, enhanced oil recovery from underground reservoirs is under investigation using surfactants, polymers, emulsions, and foams.

Courses

Stated prerequisites for each course indicate the desirable background level. Students majoring in other engineering or physical science fields should consult the instructor to determine whether they have acquired sufficient preparation.

Lower Division Courses

24. Freshman Seminars. (1) One hour of seminar per week. Section 1 to be graded on a letter-grade basis. Section 2 to be graded on a *passed/not passed* basis. The Berkeley Seminar Program has been designed to provide new students with the opportunity to explore an intellectual topic with a faculty member in a small-seminar setting. Berkeley seminars are offered in all campus departments, and topics vary from department to department and semester to semester. May be repeated for credit as topic varies.

84. Sophomore Seminar. (1-2) One hour of seminar per week per unit for 15 weeks. One and one-half hours of seminar per week per unit for 10 weeks. Two hours of seminar per week per unit for eight weeks. Three hours of seminar per week per unit for five weeks. Sections 1-2 to be graded on a *passed/not passed* basis. Sections 3-4 to be graded on a letter-grade basis. *Prerequisites: At discretion of instructor.* Sophomore seminars are small interactive courses offered by faculty members in departments all across the campus. Sophomore seminars offer opportunity for close, regular intellectual contact between faculty members and students in the crucial second year. The topics vary from department to department and semester to semester. Enrollment limited to 15 sophomores. May be repeated for credit as topic varies.

C96. Introduction to Research and Study in the College of Chemistry. (1) One hour of seminar per week. Must be taken on a *passed/not passed* basis. *Prerequisites: Freshman standing in chemistry, chemical biology, or chemical engineering major, or consent of instructor. Chemistry and chemical biology majors enroll in Chemistry C96 and chemical engineering majors enroll in Chemical Engineering C96.* Introduces freshmen to research activities and programs of study in the College of Chemistry. Includes lectures by faculty, an introduction to college library and computer facilities, the opportunity to meet alumni and advanced undergraduates in an informal atmosphere, and discussion of college and campus resources. Also listed as Chemistry C96. *(F)*

98. Directed Group Studies for Lower Division Undergraduates. (1-3) Course may be repeated for credit. One hour of work per week per unit. Must be taken on a *passed/not passed* basis. *Prerequisite: Consent of instructor.* Supervised research on a specific topic. Enrollment is restricted; see the "Introduction to Courses and Curricula" section of the *General Catalog.*

Upper Division Courses

140. Introduction to Chemical Process Analysis. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: Chemistry 4B (or 1B) with a grade of C- or better; Physics 7B, which may be taken concurrently.* Material and energy balances applied to chemical process systems. Determination of thermodynamic properties needed for such calculations. Sources of data. Calculation procedures. *(F)*

141. Chemical Engineering Thermodynamics. (3) Three hours of lecture and one hour of discussion per week. *Prerequisites: 140 with a grade of C- or higher; Engineering 7, which may be taken concurrently, or an acceptable computer programming transfer course.* Thermodynamic behavior of pure substances and mixtures. Properties of solutions, phase equilibria. Thermodynamic cycles. Chemical equilibria for homogeneous and heterogeneous systems. *(S)*

142. Chemical Kinetics and Reaction Engineering. (3) Three hours of lecture and one hour of discussion per week. *Prerequisites: 141, 150B.* Analysis and prediction of rates of chemical conversion in flow and nonflow processes involving homogeneous and heterogeneous systems. *(S)*

150A. Transport Processes. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 140 with a grade of C- or higher; Math 54, which may be taken concurrently.* Principles of fluid mechanics and heat transfer with application to chemical processes. Laminar and turbulent flow in pipes and around submerged objects. Flow measurement. Heat conduction and convection; heat-transfer coefficients. *(S)*

150B. Transport and Separation Processes. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 150A with a grade of C- or higher; Engineering 7 or an acceptable computer programming transfer course.* Principles of mass transfer with application to chemical processes. Diffusion and convection. Simultaneous heat and mass transfer; mass transfer and coefficients. Design of staged and continuous separations processes. *(F)*

154. Chemical Engineering Laboratory. (3) One hour of lecture and eight hours of laboratory per week. *Prerequisites: 142, 150B, Engineering 190.* Experiments in physical measurements, fluid mechanics, heat and mass transfer, kinetics, and separation processes. Emphasis on investigation of basic relationships important in engineering. Experimental design, analysis of results, and preparation of engineering reports are stressed. *(F, S)*

157. Transport Processes Laboratory. (3) One hour of lecture and five hours of laboratory per week. *Prerequisites: 150A; 150B (may be taken concurrently).* Physicochemical properties of materials. Fluid mechanics, heat and mass transfer experiments illustrating principles and applications of transport phenomena in chemical engineering practice. Experiments illustrate the application of chemical engineering principles to modern technologies such as microelectronics processing, biotechnology, and materials processing. *(F, S)*

160. Chemical Process Design. (4) Three hours of lecture, one hour of discussion, and three hours of computer lab per week. *Prerequisites: 142, 150B.* Design principles of chemical process equipment. Design of integrated chemical processes with emphasis upon economic considerations. *(F, S)*

162. Dynamics and Control of Chemical Processes. (4) Three hours of lecture and one hour of discussion per week. *Prerequisites: 150B, Math 53, Math 54.* Analysis of the dynamic behavior of chemical processes and methods and theory of their control. Implementation of computer control systems on process simulations. *(F, S)*

170A. Biochemical Engineering. (3) *Formerly 170.* Three hours of lecture per week. *Prerequisite: 150B or consent of instructor.* The first of a two-semester sequence intended to introduce chemical engineers to the basic concepts of biochemical engineering. The course focuses on the use of chemical engineering skills and principles in the analysis and design of biologically-based processes. No previous background in the biological sciences has been assumed, and no subsection of the course has been set aside to cover fundamental topics in biochemistry, molecular biology, or microbiology. Instead, such material will be introduced as necessary throughout the course. The main emphasis of the 170A-170B sequence will be on biochemical kinetics, heat and mass transfer, thermodynamics, and transport phenomena as they apply to enzyme catalysis, protein engineering, microbial growth and metabolism, fermentation and bioreactor design, product recovery, and downstream processing. *(F)*

170B. Biochemical Engineering. (3) *Formerly 170.* Three hours of lecture per week. *Prerequisite: 170A.* The second of a two-semester sequence intended to introduce chemical engineers to the basic concepts of biochemical engineering. The course focuses on the use of chemical engineering skills and principles in the analysis and design of biologically-based processes. The main emphasis of the 170A-170B sequence will be on biochemical kinetics, heat and mass transfer, thermodynamics, and transport phenomena as they apply to enzyme catalysis, protein engineering, microbial growth and metabolism, fermentation and bioreactor design, product recovery, and downstream processing. *(S)*

C170L. Biochemical Engineering Laboratory. (3) Six hours of laboratory and one hour of lecture per week. *Prerequisite: 170A (may be taken concurrently) or consent of instructor.* Laboratory techniques for the cultivation of microorganisms in batch and continuous reactions. Enzymatic conversion processes. Recovery of biological products. Also listed as Chemistry C170L. *(S)*

171. Transport Phenomena. (3) Three hours of lecture per week. *Prerequisite: 150B.* Study of momentum, energy, and mass transfer in laminar and turbulent flow. *(S)*

176. Principles of Electrochemical Processes. (3) Three hours of lecture per week. *Prerequisites: 141, 150B.* Principles and application of electrochemical equilibria, kinetics, and transport processes. Technical electrolysis and electrochemical energy conversion.

C178. Polymer Science and Technology. (3) Three hours of lecture per week with some lectures replaced by a three-hour laboratory. *Prerequisites: 150A or equivalent fluid mechanics or consent of instructor; one semester of organic chemistry and physics recommended.* Introduction to physical and chemical behavior of organic polymers. Properties of solutions, melts, glasses, elastomers, and crystals. Engineering applications, emphasizing processing technology. Experiments in polymerization and characterization. Also listed as Chemistry C178. *(F)*

179. Process Technology of Solid-State Materials Devices. (3) Three hours of class meetings per week with five lectures replaced by a three-hour laboratory. *Prerequisites: Engineering 45; one course in electronic circuits recommended; senior standing.* Chemical processing and properties of solid-state materials. Crystal growth and purification. Thin film technology. Application of chemical processing to the manufacture of semiconductors and solid-state devices. *(S)*

185. Technical Communication for Chemical Engineers. (3) Three hours of lecture per week. *Prerequisites: 140; satisfactory completion of UC Entry-Level Writing requirement; satisfaction of the ChemE English composition requirement and satisfactory language skills as judged by instructor.* Development of technical writing and oral presentation skills in formats commonly used by chemical engineers. May be repeated with consent of instructor. *(F, S)*

H194. Research for Advanced Undergraduates. (2-3) Individual conferences. *Prerequisites: Honors and senior standing; a minimum GPA of 3.4 overall at Berkeley.* Original research under direction of one of the members of the staff. May be repeated for credit. *(F, S)*

195. Special Topics. (2-4) Individual conferences. *Prerequisite: Consent of instructor.* Lectures and/or tutorial instruction on special topics. May be repeated for credit. *(F, S)*

196. Special Laboratory Study. (2-3) Individual conferences. *Prerequisites: Senior standing and consent of instructor.* Special laboratory or computation work under direction of one of the members of the staff. May be repeated for credit. *(F, S)*

197. Field Study in Chemical Engineering. (1-4) Course may be repeated for credit. Three hours of field work per week per unit. Must be taken on a *passed/not passed* basis. *Prerequisites: Upper division standing and consent of instructor.* Supervised experience in off-campus organizations relevant to specific aspects and applications of chemical engineering. Written report required at the end of the term. This course does not satisfy unit or residence requirements for the bachelor's degree. *(F, S)*

198. Directed Group Study for Undergraduates. (1-3) Course may be repeated for credit. One hour of lecture per week per unit. Must be taken on a *passed/not passed* basis. *Prerequisite: Completion of 60 units of undergraduate study and in good academic standing.* Supervised research on a specific topic. Enrollment is restricted; see the "Introduction to Courses and Curricula" section of the *General Catalog*.

Graduate Courses

230. Mathematical Methods in Chemical Engineering. (3) Three hours of lecture per week. *Prerequisites: Math 53 and 54, or equivalent; open to seniors with consent of instructor.* Mathematical formulation and solution of problems drawn from the fields of heat and mass transfer, fluid mechanics, thermodynamics, and reaction kinetics employing ordinary and partial differential equations, variational calculus, and Fourier methods. *(F)*

232. Computational Methods in Chemical Engineering. (3) Three hours of lecture per week. *Prerequisite: 230. Open to senior honor students.* Introduction to modern computational methods for treatment of problems not amenable to analytic solutions. Application of numerical techniques to chemical engineering calculations with emphasis on computer methods.

240. Thermodynamics for Chemical Product and Process Design. (3) Three hours of lecture per week. *Prerequisites: Math 53 and 54, or equivalent; 141 or equivalent; open to seniors with consent of instructor.* First and second laws of thermodynamics, thermodynamic calculus. Criteria for thermodynamic equilibrium. Thermodynamic properties of pure materials and their relation to molecular constitution. Mixtures. Phase equilibria, chemical reaction equilibria. Thermodynamics of systems under stress, or in electric, magnetic, or potential fields. *(F)*

241. Molecular Thermodynamics for Phase Equilibria in Chemical Engineering. (2) Two hours of lecture per week. *Prerequisite: 141 or equivalent.* Engineering-oriented synthesis of molecular models with statistical and classical thermodynamics. Quantitative representation of vapor-liquid, liquid-liquid, and solid-fluid equilibria. In addition, to phase equilibria for conventional, chemical, and petrochemical industries, attention is given to supercritical extraction, polymers, gels, electrolytes, adsorption, hydrates, and to selected topics in biothermodynamics.

244. Kinetics and Reaction Engineering. (3) Three hours of lecture per week. *Prerequisites: 142 and 230, or equivalent; open to seniors with consent of instructor.* Microscopic processes in chemical reactors: kinetics, catalysis. Interaction of mass and heat transfer in chemical processes. Performance of systems with chemical reactors.

245. Catalysis. (3) Three hours of lecture per week. *Prerequisite: 244 or Chemistry 223, or consent of instructor.* Adsorption and kinetics of surface reactions; catalyst preparation and characterization; poisoning, selectivity, and empirical activity patterns in catalysis; surface chemistry, catalytic mechanisms, and modern experimental techniques in catalytic research; descriptive examples of industrial catalytic systems.

246. Principles of Electrochemical Engineering. (3) Three hours of lecture per week. *Prerequisite: Graduate standing or consent of instructor.* Electrode processes in electrolysis and in galvanic cells. Charge and mass transfer in ionic media. Criteria of scale-up.

248. Applied Surface and Colloid Chemistry. (3) Three hours of lecture per week. *Prerequisite: Graduate standing or consent of instructor.* Principles of surface and colloid chemistry with current applications; surface thermodynamics, wetting, adsorption from solution, disperse systems, association colloids, interacting electrical double layers and colloid stability, kinetics of coagulation, and electrokinetics.

249. Biochemical Engineering. (3) Three hours of lecture per week. *Prerequisites: 150A, 150B, Molecular and Cell Biology 102, Chemistry 112B, 120B, or consent of instructor*. Application of chemical engineering principles to the processing of biological and biochemical materials. Design of systems for cultivation of microorganisms and for the separation and purification of biological products.

250. Transport Processes. (3) Three hours of lecture per week. *Prerequisites: 150A, 150B, and 230, or equivalent; open to seniors with consent of the instructor.* Basic differential relations of mass, heat, and momentum transport for Newtonian and non-Newtonian fluids; exact solutions of Navier-Stokes equations; scaling and singular perturbations; creeping flow; laminar boundary layers; turbulence; hydrodynamic stability. *(S)*

256. Advanced Transport Phenomena. (3) Three hours of lecture per week. *Prerequisite: 230.* Formulation and rigorous analysis of the laws governing the transport of momentum, heat, and mass, with special emphasis on chemical engineering applications. Detailed investigation of laminar flows complemented by treatments of turbulent flow systems and hydrodynamic stability.

C268. Physicochemical Hydrodynamics. (3) Three hours of lecture per week. *Prerequisite: A first graduate course in fluid mechanics is recommended.* An introduction to the hydrodynamics of capillarity and wetting. Balance laws and short-range forces. Dimensionless numbers, scaling, and lubrication approximation. Rayleigh instability. Marangoni effect. The moving contact line. Wetting and short-range forces. The dynamic contact angle. Dewetting. Coating flows. Effect of surfactants and electric fields. Wetting of rough or porous surfaces. Contact angles for evaporating systems. Also listed as Mechanical Engineering C268. *(F)*

295. Special Topics in Chemical Engineering. *Prerequisite: Open to properly qualified graduate students.* Current and advanced study in chemical engineering, primarily for advanced graduate students.

295B. Electrochemical, Hydrodynamic, and Interfacial Phenomena. (2) Two hours of lecture per week. *Prerequisite: Open to properly qualifed graduate students.* Course may be repeated for credit. *(F)*

295D. Development of Biopharmaceuticals. (2) Two hours of lecture per week. *Prerequisite: Graduate standing or consent of instructor.* This course will present the process of taking a discovered biological activity through steps leading to a pharmaceutical product fit for marketing to the public. Students will gain an understanding of product development in a modern biotechnology company. This course focuses on pharmaceuticals produced by biotechnology and from human blood plasma.

295F. Battery Technologies: Addressing the Growing Demand for Electrical Energy Storage. (3) Three hours of lecture per week. *Prerequisite: Properly qualified graduate students with consent of instructor(s).* Incorporating ideas from a variety of disciplines, this course aims to equip students with the concepts and analytical skills necessary to assess the utility and viability of various battery technologies in the context of a growing demand for electrochemical energy storage. The course will focus on the fundamentals of electrochemical energy storage with respect to the physical principles of operation, design, and manufacturing of various battery technologies. Traditional chemical engineering science is integrated with the practical issues of manufacturing, cost and market analysis, and policy considerations to provide a complete picture of the engineering and development of modern battery storage systems. *(F)*

295K. Current Topics in Metabolic Engineering. (1) One hour of lecture per week. *Prerequisites: 170 or equivalent, MCB 102 or equivalent, or consent of instructor.* This course will survey recent advances in metabolic engineering and will survey the recent literature in this area. Topics of interest include flux analysis, recombinant gene expression, metabolomics, proteomics, transcriptomics, physiology, microbial secondary metabolites. Students will be expected to read and interpret the recent literature. A working knowledge of molecular biology is necessary.

C295L. Implications and Applications of Synthetic Biology. (3) *Formerly C200.* Two hours of lecture and one hour of discussion per week. *Prerequisite: Consent of instructor.* Explore strategies for maximizing the economic and societal benefits of synthetic biology and minimizing the risks. Create “seedlings” for future research projects in synthetic biology at Berkeley. Increase multidisciplinary collaborations at Berkeley on synthetic biology. Introduce students to a wide perspective of SB projects and innovators as well as policy, legal, and ethical experts. Also listed as Bioengineering C230. *(S)*

C295M. Topics in Fluid Mechanics. (1-2) Course may be repeated for credit. One hour of seminar per week. Must be taken on a *satisfactory/unsatisfactory* basis. *Prerequisite: Consent of instructor.* Lectures on special topics which will be announced at the beginning of each semester that the course is offered. Topics may include transport and mixing, geophysical fluid dynamics, bio-fluid dynamics, oceanography, free surface flows, non-Newtonian fluid mechanics, among other possibilities. Also listed as Bioengineering C290C, Mechanical Engineering C298A, Civil and Environmental Engineering C290K, Nuclear Engineering C290F, Mathematics C290C, Physics C290I, and Environmental Science, Policy, and Management C291.

295N. Polymer Physics. (3) Three hours of lecture per week. *Prerequisites: 230, 240.* This course, which is based on Gert Strobl's book, *The Physics of Polymers,* addresses the origin of some of the important physical properties of polymer liquids and solids. This includes phase transitions, crystallization, morphology of multi-phase polymer systems, mechanical properties, response to mechanical and electric fields, and fracture. When possible, students will develop quantitative molecular models that predict macroscopic behavior. The course will address experimental data obtained by microscopy, light and neutron scattering, rheology, and dielectric relaxation.

295O. Chemical Engineering Management. (3) One two-hour lecture per week. *Prerequisite: Graduate standing or consent of instructor.* Students will participate in solving open-ended technical and business problems facing management in an industrial organization. Emphasis will be on problem synthesis, creative and strategic thinking, and communication skills. Objectives of the course are to provide an understanding (1) of what is expected of a new engineer in industry, (2) of the viewpoint of management, and (3) of the skills needed for success.

295P. Introduction to New Product Development. (3) Three hours of lecture per week. *Prerequisites: Graduate standing or consent of instructor.* This course is part of the product development initiative sponsored by the Department of Chemical Engineering. It focuses on real-life practices and challenges of translating scientific discovery into commercial products. Its scope is limited in most circumstances to situations where some knowledge of chemical engineering, chemistry, and related disciplines might prove to be particularly useful. The course primarily uses case studies of real-world new product development situations to simulate the managerial and technical challenges that will confront students in the field. The course will cover a wide range of topics including basic financial, strategic, and intellectual property concepts for products, managing risk and uncertainty, the effective new product development team, the evolving role of corporate R&D, the new venture product company, and the ethics of post-launch product management. *(F)*

295Q. Advanced Topics in New Product Development. (3) Three hours of lecture per week. *Prerequisites: Graduate standing or consent of instructor; 295P recommended.* This course is a part of the product development initiative sponsored by the Department of Chemical Engineering. The course builds on the coverage in 295P of real-life practices of translating scientific discovery into commercial products. The course will cover a wide range of advanced product development concepts including technology road maps, decision analysis, six sigma, product portfolio optimization, and best practices for field project management. *(S)*

C295R. Applied Spectroscopy (3) Three hours of lecture per week. *Prerequisites: Graduate standing in engineering, physics, chemistry, or chemical engineering; courses in quantum mechanics and linear vector space theory.* After a brief review of quantum mechanics and semiclassical theories for the interaction of radiation with matter, this course will survey the various spectroscopies associated with the electromagnetic spectrum, from gamma rays to radio waves. Special emphasis is placed on application to research problems in applied and engineering sciences. Graduate researchers interested in systematic *in situ* process characterization, analysis, or discovery are best served by this course. Also listed as Applied Science and Technology C295R.

295S. Introduction to Experimental Surface Chemistry. (3) Three hours of lecture per week. *Prerequisite: 240 or equivalent.* This course is intended to introduce chemical engineering students to the concepts and techniques involved in the study of chemical processes at surfaces. Special emphasis will be placed on the chemistry of semiconductor surfaces. Topics to be covered include: thermodynamics and kinetics of surfaces; crystal and electronic structures of clean surfaces (metals and semiconductors); adsorption and desorption; surface kinetics and dynamics including diffusion; dynamics of growth and etching; surface reaction models; a survey of modern surface analytical techniques including electron diffraction, auger electron spectroscopy, photoelectron spectroscopy, vibrational spectroscopy, scanning tunneling microscopy, and mass spectrometry.

296. Special Study for Graduate Students in Chemical Engineering. (1-6) Individual conferences. Must be taken on a *satisfactory/unsatisfactory* basis. *Prerequisite: Consent of instructor.* Special laboratory and theoretical studies. May be repeated for credit. *(F, S)*

298. Seminar in Chemical Engineering. (1) Variable from one to two-hour meetings per week. *Prerequisite: Open to properly qualified graduate students with consent of instructor.* Lectures, reports, and discussions on current research in chemical engineering. Sections are operated independently and directed toward different topics. May be repeated for credit. *(F, S)*

299. Research in Chemical Engineering. (1-12) Individual conferences. *Prerequisite: Consent of instructor.* May be repeated for credit. *(F, S)*

602. Individual Studies for Graduate Students. (1-8) Individual conferences. Must be taken on a *satisfactory/unsatisfactory* basis. *Prerequisite: Graduate standing in Ph.D. program.* Individual study in consultation with the major field adviser for qualified students to prepare themselves for the various examinations required of candidates for the Ph.D. May not be used for unit or residence requirements for the doctoral degree. May be repeated for credit. *(F, S)*

Professional Course

300. Profession Preparation: Supervised Teaching of Chemical Engineering. (2) Individual conferences and participation in teaching activities. Must be taken on a *satisfactory/unsatisfactory* basis. *Prerequisites: Graduate standing, appointment as a graduate student instructor, or consent of instructor.* Discussion, problem review and development, guidance of large scale laboratory experiments, course development, supervised practice teaching. May be repeated for credit. *(F, S)*

Chemistry as a Profession

In its many facets, the study of chemistry deepens and enriches our understanding of the natural world, and in doing so it draws on the knowledge of the other major sciences. Chemists study systems of atoms and molecules from temperatures near absolute zero to temperatures as high as those found on the sun. They study the properties of matter at the very low pressures that are encountered in interstellar space and at the very high pressures found in the center of the earth. Nuclear chemists study the structure and changes that occur in the nucleus of atoms, while biophysical chemists deal with very large molecules that are the building blocks of life.

Chemists analyze the mechanism or the steps in the process by which atoms can form a molecule upon collision, or by which chains of molecules act as ingredients to make a polymer. They bring these atoms or chains of molecules together in unique ways to form substances that have never been prepared before, and at the same time develop techniques to characterize the composition, bonding, and structure of these new materials.

Today, research in chemistry includes the monitoring and removal of pollutants from the atmosphere; the study of chromosomes, genes, and DNA replication; investigation of polysaccharides that decorate the surface of cells; elucidation of the role of small molecules in cell signalling; the production, conversion, and storage of energy; research on photosynthesis; the development of fertilizers that help produce rich harvests; and the continuing research on the creation of new materials for nanotechnology and for medical applications.

The many applications of chemistry to our lives have created a broad range of opportunities for employment. Chemistry is an integral part of the nation's economy, and the central discipline in a major industry of its own. With either a B.A. or a B.S. degree in chemistry or a B.S. degree in chemical biology, a student may find a research or technical position in a variety of industries such as oil, chemical, food processing, agriculture, photographic, pharmaceutical, biotechnology, and mining. In addition to the research and testing side of private employment, graduates with a knowledge of chemistry work in sales and plant development, quality control, customer relations, and many other aspects of modern business. Students who combine a strong basic background in chemistry with further studies in business administration will find many opportunities in management, development, and administration available to them.

Combining the bachelor's degree in chemistry or chemical biology with a higher degree in another field can lead to many unique and rewarding careers. The B.A. in chemistry or B.S. in chemical biology is particularly useful for those who are interested in medical school and a professional career in medical research. A chemistry B.A. with a law degree can create a career in environmental or patent law. For the student who wants to make research in chemistry a primary occupation, however, a higher degree in chemistry is essential. A Ph.D. in chemistry can lead to a career in private industry, government, or education.

The nation's concern about energy, the environment, and the detection of hazardous substances has added to the government's need for informed technical opinions on these subjects. The large national laboratories and many smaller ones provide constant opportunities for Ph.D. chemists to help shape the country's future in these crucial areas.

The Department of Chemistry

The chemistry department provides the opportunity for an undergraduate student to obtain a thorough fundamental knowledge of all fields of chemistry. There are lecture courses in the general areas of inorganic, organic, and physical chemistry, plus many more specialized courses including analytical, nuclear, and biophysical chemistry and chemical biology. Laboratory experience is provided in inorganic and organic synthesis, analytical methods, physical chemical measurements, spectroscopy, biochemical engineering, and chemical methods in nuclear technology. Independent and original work is stressed in the laboratories and modern equipment is available to carry out the work. The equipment and techniques available to the undergraduate student include nuclear magnetic resonance, electron paramagnetic resonance, visible, ultraviolet, and infra-red spectrometers, X-ray diffraction, mass spectrometry, high-vacuum, high-pressure, and low-temperature equipment, gas chromatography, and others. Many of these instruments are interfaced directly to computers; in other cases, data analysis and graphics displays are accomplished using the College of Chemistry Computer Facility. In addition, special arrangements can be made to use many specialized research techniques available on the campus.

More important than the formal lecture and laboratory courses is the intellectual environment provided by the department. There is a student commons room that makes it convenient for students to learn from one another. The Chemistry Library has an excellent collection of books, journals, and reference materials. Graduate student instructors who are themselves graduate students working toward Ph.D. degrees are further sources of scientific information and help. Faculty members are available as academic advisers and hold office hours for consultation about their courses; they are also willing to discuss chemistry, science, career opportunities, and even philosophy. The best way to take full advantage of the scientific opportunities available in the department is to join a research group. This can be done through courses for advanced undergraduates, or simply as an employee.

Graduate study at Berkeley is mainly individual learning in a research field chosen by the student. New students begin research shortly after arriving in Berkeley and usually complete their thesis work in about five years or less. Courses are normally taken only during the first two years, but seminars are a rich source of new knowledge throughout the entire graduate career. All graduate students are required to be graduate student instructors for a minimum of three semesters. Teaching is not only an essential service; it is an excellent method for learning. Financial support for graduate students is provided by graduate student instructor positions, research assistantships, and fellowships.

There is currently an active graduate student organization whose membership includes all graduate students in the college. The overall goal of this organization is to give graduate students involvement in the department and to provide a sense of community among the various separate subdisciplines in the college as well as to increase communication among faculty, administration, and students.

Statement of Intent to Accommodate Students with Disabilities. As is noted in the "Nondiscrimination Statement" at the back of this announcement, the Department of Chemistry does not discriminate negatively on the basis of race, color, national origin, sex, handicap or age in any aspect of its program. In particular, the College of Chemistry assures graduate students with physical disabilities that their needs will be accommodated in the design, construction and operation of the equipment used to carry out their research projects. This policy includes any necessary modification of existing equipment and auxiliary laboratory facilities required to carry out the project.

Undergraduate Programs

Choice of College and Major

A student can complete a major in chemistry or chemical biology in the College of Chemistry (B.S. degree) or a major in chemistry in the College of Letters and Science (B.A. degree).

The **Bachelor of Science Degree in Chemistry** is intended to prepare students for careers as professional chemists and to serve as a foundation for careers in other fields such as biology and medicine. In addition, there is a Materials Chemistry concentration that is intended for students interested in the application of basic chemical principles to the discovery, design, and characterization of materials.

The **Bachelor of Science Degree in Chemical Biology** is intended for students who are interested in careers in biochemistry, the biological sciences, medicine, pharmacology, and bioengineering.

The **Bachelor of Arts Degree in Chemistry,** which is offered through the College of Letters and Science, includes a greater number of humanities and social science courses and is intended for those interested in careers in teaching, medicine, or other sciences in which a basic understanding of chemical processes is necessary.

All three curricula are satisfactory foundations for a career in the chemical industry, for the teaching of chemistry, and, if completed with high academic standing, for graduate work in chemistry and related disciplines.

The chemistry programs at Berkeley are approved by the American Chemical Society (ACS). For students to be certified to the ACS, certain courses in addition to those required for the degree must be completed. Certified graduates are eligible to become members of the ACS. Individuals with degrees that are not certified can join as associate members and can apply for full membership after three years of professional experience, such as graduate work.

Additional information on ACS certification is available in the College of Chemistry Undergraduate Majors Office, 420 Latimer Hall.

To be considered for certification to the ACS, during the final semester the student must submit an ACS certification form to the College of Chemistry Undergraduate Majors Office.

The Bachelor of Science Degrees in Chemistry and Chemical Biology

To graduate with a B.S. degree, the student must have:

- fulfilled the degree requirements and scholarship requirements as specified on pages 8 and 9 of this announcement;
- satisfactorily completed a *minimum of 120 units;* and
- satisfied the specific lower division and upper division requirements for the chosen major.

Lower Division Requirements

During the freshman and sophomore years, it is important to complete the following requirements:

Reading and Composition. The student must demonstrate reasonable proficiency in English composition by completion of a first-level course (e.g., English 1A) and a second-level course (e.g., Rhetoric 1B) from the group of courses listed in this announcement under “Breadth Requirement Course List: Group I (Reading and Composition).” The first-level and second-level courses need not be from the same department.

Students who plan to take English at another institution during a summer term or before readmission to Berkeley should check with the College of Chemistry Undergraduate Majors Office for verification of course acceptance. After admission to Berkeley, credit for English at another institution will not be granted if the Entry-Level Writing requirement has not yet been satisfied.

[1]**15-Unit Breadth Requirement.** Courses satisfying this requirement must total 15 or more units. The courses taken to satisfy the English composition requirement (above) are included in these 15 units. In addition, two or more courses in the humanities and/or social sciences must be taken. The humanities and/or social science courses may not all be in the same department. Refer to the “Breadth Requirement Course List” in the “General Information” section of this publication.

[1]**Foreign Language Requirement.** Students must complete the requirement with *one* foreign language, in one of the following ways:

1. By completing in high school the third year of one foreign language with minimum grades of C-.

2. By completing at Berkeley the second semester of a sequence of courses in one foreign language, or the equivalent at another institution. Only foreign language courses that include reading and composition as well as conversation are accepted in satisfaction of this requirement.

3. By demonstrating equivalent knowledge of a foreign language through examination, including a College Entrance Examination Board (CEEB) Advanced Placement Examination with a score of 3 or higher (if taken before admission to college), an SAT II: Subject Test with a score of 590 or higher, or a proficiency examination offered by some departments at Berkeley or at another campus of the University of California.

Students should satisfy this requirement by the end of their third year (90 semester units).

Freshman Seminar. Chemistry C96 introduces entering freshmen to research and study in the College of Chemistry. Students who enter the College of Chemistry as freshmen are required to take the course during their first fall semester at Berkeley. Enrollment in the course is restricted to students who recently entered the College of Chemistry.

Chemistry. 4A, 4B, 112A, 112B. Students study general chemistry and quantitative analysis (4A and 4B) in a two-semester series. Students should take 4A-4B during their freshman year and 112A-112B (organic chemistry) during their sophomore year.

Note: Students who join the program after completing a general chemistry sequence that does not include quantitative analysis are required to take Chemistry 4B, 15, or 105.

For chemical biology majors transferring into the College of Chemistry following their freshman year, substitution of 3A plus 3AL and 3B plus 3BL is allowed if the sequence is started before transfer into the College of Chemistry, but 112A and 112B are recommended.

(*Note:* A grade of C- or better is required in Chemistry 4A before taking 4B, in 4B before taking more advanced courses, and in 112A before taking 112B. A grade of C- or better is required in Chemistry 112A before taking Biology 1A.)

Mathematics. 1A, 1B, 53, 54. This program should start in the first semester of the freshman year.

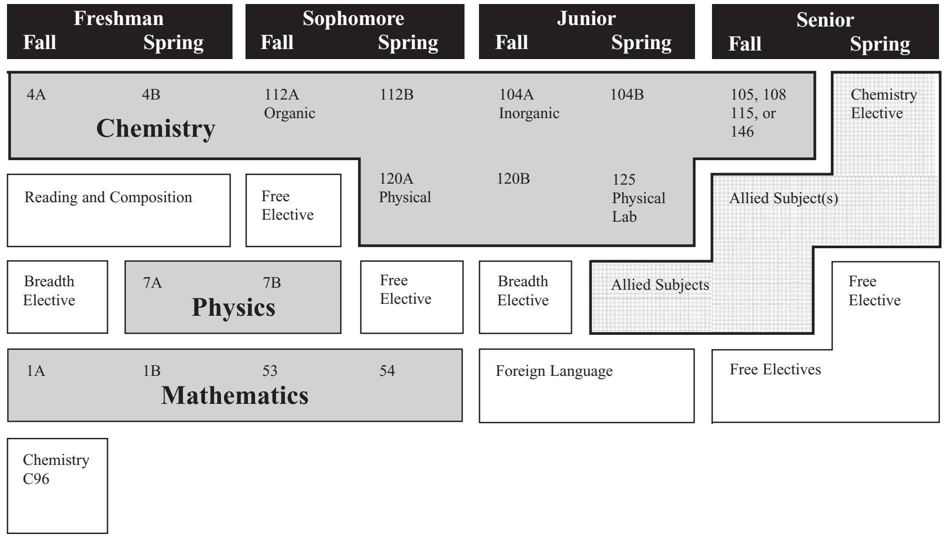
Physics. 7A, 7B. This program should start in the second semester of the freshman year.

For chemical biology majors, substitution of Physics 8A, 8B is allowed, but 7A, 7B are recommended.

Biology. 1A and 1AL. This is required for the chemical biology major only.

[1]May be taken on P/NP basis.

Representative Undergraduate Chemistry Program



The following program is suggested for the first two years:

Suggested Lower Division Program for Chemistry or Chemical Biology

	Units	
Freshman Year	*Fall*	*Spring*
Chemistry 4A-4B	4	4
Chemistry C96	1	-
Mathematics 1A-1B	4	4
Physics 7A	-	4
English Composition	4	4
[1]Breadth Elective	3-4	-
[2]**Total**	**16-17**	**16**
Sophomore Year		
Chemistry 112A-112B	5	5
Mathematics 53-54	4	4
Physics 7B	4	-
Chemistry 120A for chemistry majors or Biology 1A and 1AL for chemical biology majors	-	3-5
Free Elective	3	3
Total	**16**	**15-17**

Chemistry Major Upper Division Requirements

During their junior and senior years students must complete the following course requirements:

Chemistry. 104A, 104B, 120A, 120B, 125 and *one* of the following choices: 105, 108, 115, or 146. (*Note:* Chemistry C182 may be substituted for 125.)

(*Note:* A grade of C- or higher is required in Chemistry 120A or 120B if taken before 125.)

15 Units of Upper Division Chemistry and Allied Subjects. *In addition to the requirements listed above,* the following must be completed to total at least 15 units:

- an additional lecture course (or laboratory/lecture course) in chemistry as approved by your staff adviser; and
- additional courses in chemistry and/or related fields. See the list of "Allied Subject Courses" that follows this section.

This program may be used to specialize in a particular area of chemistry, such as inorganic, nuclear, organic, or physical. The program may also be used to develop an understanding in other fields of interest that require a strong background in chemistry, such as biochemistry, chemical physics, chemical engineering, geochemistry, materials science (polymers, metals, ceramics), atmospheric chemistry, etc.

The program may also be used to specialize in the area of environmental science. Students majoring in chemistry have enough depth of training so that they can usefully participate in defining and finding chemical solutions to problems of chemical pollution. As a complement to chemical studies, an understanding of biological, ecological, geological, public health, and social sciences is useful. The 15-unit program should have a clear focus on the environment and should include courses from these disciplines and additional courses in the general area. Detailed programs should be worked out by the student and faculty adviser.

Premedical students with a strong interest in chemistry, perhaps planning a career in medical research, may include in the program the specific premedical requirements. The chemistry and physics required for the B.S. in chemistry satisfy premedical requirements for these subjects.

In all cases it is the student's responsibility to develop a coherent 15-unit program and to obtain approval of the overall program from the student's adviser. The associate dean of the college must approve a program that is at variance with the norms described above.

Materials Chemistry Concentration Upper Division Requirements

Chemistry majors who choose a concentration in materials chemistry must complete the following course requirements during their junior and senior years:

Chemistry. 104A, 104B, 120A, 120B, C150, and two laboratory courses as follows: 105 or 125; plus 108 or 115.

10 Units of Upper Division Electives. In addition to the chemistry courses listed above, 10 units of upper division electives must be completed from the following: Bioengineering C118, Chemistry C178, Materials Science and Engineering 104, Mechanical Engineering 118, Physics 141A, Physics 141B.

Chemical Biology Major Upper Division Requirements

During their junior and senior years students must complete the following course requirements:

Chemistry. 103, 120A, 120B, 135, and *one* of the following choices: 105, 125, C170L (or Chemical Engineering C170L), or C182.

(*Note:* A grade of C- or higher is required in Chemistry 120A or 120B if taken before 125.)

Molecular and Cell Biology. 110, 110L. Biology 1A plus 1AL and Chemistry 135 satisfy the prerequisite for Molecular and Cell Biology 110.

Seven Units of Upper Division Chemistry and Allied Subjects. In addition to the requirements listed above, the following must be completed to total at least seven units:

- an additional lecture course (or laboratory/lecture course) in chemistry as approved by your staff adviser; and
- additional course(s) in chemistry and/or related fields. See the list of "Allied Subject Courses" below.

Allied Subject Courses

No more than 4 units of research (such as 192, H194, and/or 196) may be used to satisfy this requirement.

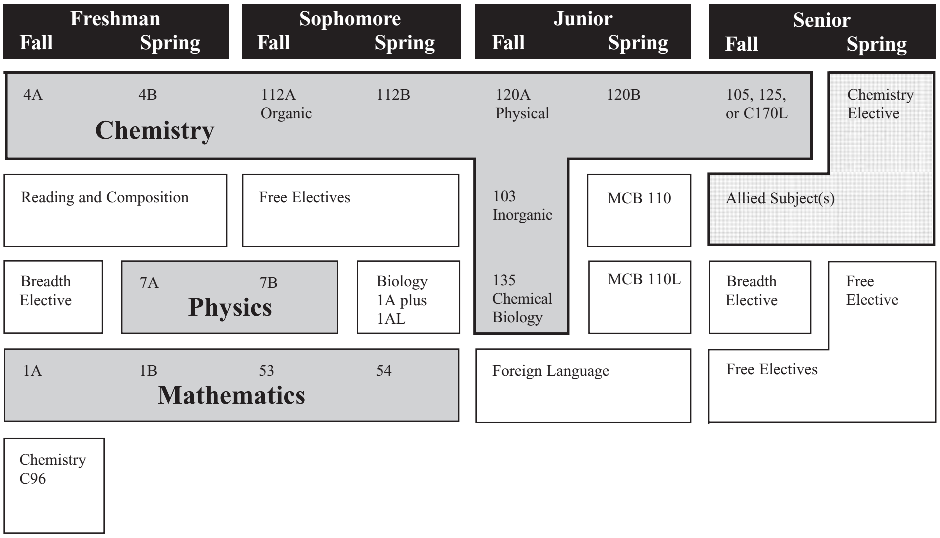
Bioengineering
115, 116, C117, C118, 121, 131, C141

Biology (for chemistry majors only)
1A plus 1AL or 1B (but not both)

Note: Biology 1A plus 1AL or 1B must be completed with a grade of C- or better to be counted as an allied subject. Neither Biology 1A plus 1AL nor 1B is accepted as an allied subject for the chemical biology major.

[1]May be taken on P/NP basis.
[2]For the first semester, students may consider taking one fewer course.

Representative Undergraduate Chemical Biology Program



Chemical Engineering
140, 141, 142, 150A, 150B, 154, 157, 160, 162, 170A, 170B, C170L, 171, 176, C178, 179, 181, H194, 195, 196

Chemistry
100 (limited to 2 units), 105, 108, 113, 114, 115, 122, 125, 135, 143, 146, C150, C170L, C178, C182, C191, 192, H194, 195, 196

Note: If a course is used to satisfy another requirement (such as the chemistry major requirement of one of 105, 108, 115, or 146), the course cannot also be used as an allied subject.

Civil and Environmental Engineering
108, 109, 111, 112, 114, 115, C116

Computer Science
160, 162, 164, 170, 174, 184, C191

Earth and Planetary Science
103, 105, 111, C129, 131, C180, C182, 185

Education
121A, 223B, 224A

Note: Enrollment in these graduate-level courses requires consent of instructor.

Electrical Engineering
100

Energy and Resources Group
102

Engineering
102, 117, 128

Environmental Science, Policy, and Management
119, 120, 126, C128, C129, C138, 180, C180

Integrative Biology
106A

Materials Science and Engineering
100, 102, 103, 104, 111, 112, C113, 117, C118, 120, 121, 122, 123, 125, 126, 130, 151

Mathematics
C103, 104, H104, 105, 110, H110, 113, H113, 114, 115, 119, 121A, 121B, 123, 125A, 126, 128A, 128B, 130, 135, 140, 142, 170, 185, H185, 187, 189

Molecular and Cell Biology
102, C103, 110, 110L, 111, C112, C112L, 113, C114, 115, C116, 130, 130L, 140, 140L, C148, 150, 150L, C160, 160L

Nuclear Engineering
101, 104, 107, 120, 124, 135, 150, 161, 162, 170A, 170B, 180

Nutritional Science and Toxicology
103, 110, C112, 113, C119, 150, 160

Physics
7C, 105, 110A, 110B, 137B, 141A, 141B, C191

Note: Physics 7C must be completed with a grade of C- or better to be counted as an allied subject.

Plant and Microbial Biology
C103, C112, C112L, C114, C116, 120, 120L, 135, 135L, C148, 150, 150L, 160, 160L, 180

Public Health
C102, 142, C143, 162A, 162L, C170B, C171, 172, C172

Statistics
101, 102, 134, 135, C141, C143

The Bachelor of Arts Degree in Chemistry

To graduate with a B.A. degree in Chemistry, the student must be in the College of Letters and Science and must have satisfied general University requirements, the American Cultures requirement, and College of Letters and Science requirements in addition to the major requirements. Detailed information about these requirements is available in the *General Catalog* and *Earning Your Degree: A Guide for Students in the College of Letters and Science.*

Major Requirements

Chemistry. 4A, 4B, 104A, 104B (103 and 135 may be taken in place of 104A, 104B), 112A, 112B, 120A, 120B, and a choice of *one* of 105, 108, 115, 125, C170L, or C182.

(*Note:* A grade of C- or better is required in Chemistry 4A before taking 4B, in 4B before taking more advanced courses, in 112A before taking 112B, and in 120A or 120B if taken before 125.)

Note: Students who declare the chemistry major after completing a general chemistry sequence that does not include quantitative analysis are required to take Chemistry 4B, 15, or 105.

Mathematics. 1A, 1B, 53, 54.

Physics. 7A, 7B.

Honors at Graduation for the B.A. Degree in Chemistry

To be eligible to receive honors in chemistry at graduation, a student must:

- complete at least three units of Chemistry H194 or another advanced chemistry course as approved by the department;
- achieve a grade point average of 3.5 or higher in upper division courses in the major; and
- achieve a grade point average of at least 3.3 overall at Berkeley.

Chemistry Minor

Note: The chemistry minor is not available to chemical biology majors.

A minor in chemistry will be awarded to students who have successfully completed one year of organic chemistry (3A plus 3AL and 3B plus 3BL, or 112A and 112B, or equivalent), one year of physical chemistry taken at Berkeley (120A-120B, or C130 and 130B), and two additional upper division chemistry courses taken at Berkeley (with the exception of courses numbered 190-199). All of the courses taken for the minor must be taken for a letter grade. Students must achieve at least a 2.0 grade point average in the courses taken for the minor for each of the following: upper division courses, courses taken at Berkeley, and organic chemistry courses if taken at another institution and accepted by the College of Chemistry as equivalent to 3A plus 3AL, 3B plus 3BL, 112A, or 112B. For the minor to be awarded, the student must submit a notification of completion of the minor at 420 Latimer Hall.

Note: Students must consult with their colleges/schools for information on rules regarding overlap of courses between their majors and minors.

Graduate Programs

Master's Degree

Normally students are not admitted to the graduate program to obtain a master's degree. The master's degree is usually sought by students who have specific objectives of preparation for professional work that are too extensive to be fulfilled in the undergraduate curricula and after deciding that the Ph.D. degree is not appropriate for them.

Two alternative programs are available, as established by the Graduate Council and adopted by the college:

- *Plan I:* 20 units of course work and a thesis based on some independent research in chemistry or chemical engineering. At least eight of the 20 units must be in courses in the 200-level in the major subject.
- *Plan II:* 24 units of course work and a comprehensive final examination. At least 12 units must be chosen in the 200-level courses in the major subject.

Students planning to receive a master's degree in chemistry will normally follow Plan II, but Plan I may be followed when space and facilities are available.

The essential undergraduate preparation for a student in chemistry, in addition to elementary work in chemistry, physics, and mathematics, includes a year of advanced inorganic chemistry and/or quantitative analysis, a year each of organic and physical chemistry including laboratory work, and a reading knowledge of German. Additional advanced work in chemistry or closely related fields is desirable.

The program of graduate study leading to a master's degree offers students with minimum preparation in chemistry opportunities to develop more extensive preparation and training in their chosen professional fields.

The master's degree in chemistry also prepares students for teaching positions in California community colleges when taken in conjunction with the necessary courses in educational methods. In many instances, it will also be possible to gain practical teaching experience as a graduate student instructor in the lower division courses in the college.

Doctor of Philosophy Degree

The objectives of the Department of Chemistry in the selection and training of candidates for the Ph.D. degree are to ensure a reasonable breadth of knowledge and to discover and develop ability to do independent and productive research. Ordinarily four to six years' study in full-time residence is needed to complete the requirements.

Records in advanced undergraduate courses are accepted as partial evidence of breadth of knowledge. Students will be encouraged and expected to extend this knowledge by taking and auditing advanced courses, both before and after advancement to candidacy. However, the graduate student has great flexibility in developing this course activity. Graduate adviser approval can be obtained for a systematic and sustained program of scientific study to supplement thesis study and research.

Because of the emphasis on creativity in the graduate studies, the student is encouraged to choose a field of research activity and a specific research problem under the direction of one of the members of the staff early in the first year.

There are a number of other requirements for the Ph.D. degree:

- A program of course work tailored to fit individual preparation and interests. Students typically take about four semester courses.
- Three semesters assisting in chemistry instruction.
- Students in organic and inorganic chemistry must submit a short written report of their research at the end of their first year. During their second year, all students present a seminar on their research or on an outside topic of current interest, and undergo an oral qualifying examination. The qualifying examination may also include an original proposition.

Chemical Biology Program

The goal of the Chemical Biology Graduate Program is to equip Ph.D. students with the training needed to propel research at the chemistry/biology interface in new and exciting directions while supporting their personal research interests.

The program is open to students who are interested in interdisciplinary research at the interface of chemistry and biology and are entering one of four Berkeley departments: chemistry, molecular and cell biology, chemical engineering, or bioengineering.

The Chemical Biology Graduate Program does not offer a degree in chemical biology. It is designed to enhance the degree granted by the student's selected home department. The program participant meets the requirements of both the Chemical Biology Graduate Program and the home department. Chemical Biology Graduate Program requirements include:

- three 10-week rotations through labs from over 36 laboratories in the above four departments;
- three poster sessions per year where first-year students present their work;
- two required courses; and
- annual retreat.

Designated Emphasis in Nanoscale Science and Engineering

Doctoral students interested in pursuing interdisciplinary research focused on nanoscale science and engineering (NSE) may additionally join the Designated Emphasis (DE) administered by the NSE Graduate Group. The DE, like a minor, is listed on the academic transcript (e.g., Ph.D. in Chemistry with Designated Emphasis in Nanoscale Science and Engineering). More information about the NSE Graduate Group and the requirements for completing the DE program is available at nano.berkeley.edu/educational/DEGradGroup.html.

Faculty Research Interests

Berkeley students and faculty are engaged in a variety of projects which cover the vital areas of chemical research more broadly than in any other department in the country. There are research programs not only in the traditional areas of analytical, inorganic, physical, and organic chemistry, but also in such diverse areas as chemical biology and nuclear, biophysical, bio-organic, and space and atmospheric chemistry.

Analytical Chemistry

Analytical and bioanalytical chemistry has undergone explosive growth in recent years due to powerful new developments in instrumentation and methods for obtaining increasing amounts of information from smaller amounts of material. The analytical research program at Berkeley encompasses a variety of areas including electrochemistry, microfabrication, nuclear magnetic resonance, and mass spectrometry. Emphasis is placed on developing new instrumentation and methods for detecting trace analytes and on methods for obtaining chemical structure and understanding fundamental processes in chemical measurements.

Main themes in electrochemical studies are in electron tunneling kinetics, dynamic processes in monolayers at the air/water interface, and development of selective electrochemical sensors based on molecular recognition phenomena. Novel optical methods are applied to air-water interfaces and to observations of atmospheric composition. Advanced microfabricated chemical analysis methods that are being developed include high speed, massively parallel separation and detection methods for the characterization of biological mixtures with high sensitivity. "Laboratories on a chip" are being designed and applied to new methods for DNA sequencing, forensics, genetic analysis and pathogen diagnostics as part of the Human Genome Project. Mass spectrometry methods for chiral recognition, stereochemical differentiation, high-speed sequencing, and direct characterization of the contents of biological cells are active areas of current research. Gas-phase ion chemistry studies are used to obtain structural information from biological molecules with the goals of increasing the information obtainable by tandem mass spectrometry of complex biomolecule mixtures.

Biophysical Chemistry and Chemical Biology

Many faculty in the College of Chemistry take an interdisciplinary approach to the study of the chemical basis for biological phenomena, combining physical, synthetic, and biochemical methods. Research directions span from the behavior of single molecules to the interactions between cells in living animals. Systems being studied include signaling proteins, enzymes, DNA and RNA, membranes, and carbohydrates. Within chemistry, the disciplines of physical, organic, and analytical chemistry all contribute valuable ideas to enhance our understanding of the complexities in biology. Progress is being made throughout this field by combining new ideas in chemistry with advances in molecular biology, biochemistry, and biophysics.

The professors in the college have many resources at their disposal to help make new breakthroughs in understanding biology from a chemical perspective. These include new synchrotron light source producing an exceptional X-ray beam for crystallography, electron microscopes equipped for diffraction work, and high field NMR spectrometers.

Use of unnatural amino acids, isotopes, and sophisticated new forms of spectroscopy are also used to probe function. The roles of metals, cofactors, and even hydrogen tunneling in enzymatic reactions are being studied. Ultrafast spectroscopy can follow extremely fast photo-induced isomerizations (such as occur during vision), electron transfer processes, and electronic energy transfer. X-ray absorption spectroscopy and XAFS are used with EPR and optical spectroscopy to unravel how energy is gathered during photosynthesis, and the role of manganese in oxygen evolution.

Key processes, such as nerve signalling and viral entrance into cells, occur at the complex interfaces presented by biological membranes. Such systems are best studied with methods that selectively detect molecules of interest, such as site directed spin labeling or fluorophore attachment. Artificial membranes are being exploited as sensitive, selective detectors of a variety of molecules.

Molecular Structure and Dynamics

Berkeley has traditionally been among the world's two or three leading centers for research in molecular spectroscopy and molecular structure. In recent years, this standard of excellence has been maintained while at the same time being significantly broadened to include a truly outstanding program of research on the dynamics of chemical reactions.

Molecular spectroscopists at Berkeley are studying the structure and spectra of unusual molecules, molecular complexes, free radicals, ions, and molecules found in interstellar space. The structure of liquids is being investigated by light scattering, thermodynamic and transport property measurements, and theoretical techniques. Magnetic resonance and laser techniques are being used to explore the structure of molecular and ionic solids and the dynamics of energy transport in these media.

Kineticists, spectroscopists, and theoreticians all are engaged in the study of molecular collision processes. The problems being studied range from elastic collisions between two helium atoms to the global kinetics of air pollution in the stratosphere.

Organic Chemistry

The organic chemistry staff is a strong combination of established scholars and vigorous young faculty. The various research programs cover a broad area, ranging from organic materials and organic synthesis to bio-organic chemistry. Some students pursue projects involving the total synthesis of complex natural products or the development of synthetic methods. Others are engaged in the preparation and characterization of novel polymers and molecular assemblies. Many of the organic students work at the interface with inorganic chemistry, studying novel organometallic structures and reactions, and at the interface with biology, elucidating biosynthetic pathways and enzyme mechanisms, or devising and evaluating compounds with biological activity.

Nuclear Chemistry

Since the early days of the first cyclotrons at Berkeley, University faculty, staff, and graduate students have used their special insights and methods to exploit the research possibilities of charged-particle accelerators at the nearby Lawrence Berkeley National Laboratory (LBNL).

With a variety of major nuclear research facilities all within a few hundred meters of the chemistry classrooms and with several faculty members engaged in different areas of research, Berkeley offers the student who is interested in nuclear chemistry an unmatched richness and breadth in research environment.

The faculty are working on a whole spectrum of research activities, including the discovery and characterization of new radioisotopes, theoretical studies of nuclear structure and reactions, as well as related atomic and molecular research in photoelectron spectroscopy (ESCA), X-ray crystallography, X-ray fluorescence, neutron and charged particle activation analysis, and environmental nuclear chemistry related to actinide separation, nuclear forensics, stockpile stewardship, and nuclear waste disposal.

Inorganic Chemistry

Research carried out by the inorganic group covers a wide range of activities at the cutting edge of this vibrant field of chemistry. Synthetic and structural chemistry is particularly strong at Berkeley. New inorganic and organometallic complexes involving d-, f-, and p-block elements are prepared and characterized, and several groups are involved in mechanistic and reactivity studies with these compounds. Several research groups are actively studying new catalytic systems for olefin polymerization and chiral synthesis. Research on the bioinorganic chemistry of iron focuses on transport and storage of this element. Medical applications of gadolinium complexes in magnetic resonance imaging (MRI) and specific sequestering agents for the actinides are examples of metal-ion-specific complexation. Research at the interface of inorganic and physical chemistry is also represented. Synthesis coupled with static and time-resolved spectroscopies are being used to study the photochemical and photophysical properties of transition metal complexes. Exciting classes of new materials are being prepared; these include extended solids, hybrid inorganic/organic frameworks, nanostructured materials, and novel polymers. Advanced solid-state materials such as superconductors, semiconductors, and charge-transporting polymers are prepared by novel synthetic routes. Structural and property studies are carried out using a wide range of state-of-the-art techniques such as single-crystal and powder X-ray diffraction, X-ray photoelectron spectroscopy, multi-nuclear magnetic resonance, and Raman spectroscopy.

Condensed Matter and Surface Science

The interests of research groups in the department span a broad range of topics in modern condensed matter and surface science. Research in these areas is based on a variety of experimental techniques and approaches: synchroton radiation; photoelectron spectroscopy; molecular beams; low-energy electron diffraction; X-ray diffraction; ultrafast laser spectroscopy; high-resolution and solid state NMR, ESR and optical spectroscopy; chemical synthesis; the measurement of thermodynamic and transport properties; second harmonic generation (SHG) and sum frequency generation (SFG)-surface vibrational spectroscopy; scanning tunneling microscope; atomic force microscope; and Coherent anti-Stokes Raman microscopy. Facilities are available for research over wide ranges of temperature, pressure and magnetic field, and in ultra-high vacuum. Topics under investigation include the atomic and electronic structure of metallic solids, intercalation compounds, metal and polymer surfaces and adsorbed layers; molecular studies of friction and lubrication; the nature of aqueous electrolyte interfaces; the hydration properties of biomolecules; single nanowire lasers; the relation of surface structure to the bonding and reactivity of adsorbed molecules; catalysis; phase transitions; superconductivity; relaxation dynamics; molecular motion and energy transfer in condensed phases; liquid crystals and polymers; high-temperature chemical reactions; and electrical, magnetic, and thermodynamic properties of novel materials.

Theoretical Chemistry

Theoretical chemistry at Berkeley covers a broad spectrum of the discipline. Experiments are carried out in all the fields for which theory is pursued. The theoretical areas include electron correlation theory, density functional theory, quantum Monte Carlo for electronic structure and internal motion, linear scaling electronic structure methods, chemical dynamics and kinetics, quantum decoherence in many body systems, quantum phase and gauge kinematics, and statistical mechanical theory of self assembly, complex material dynamics and interfacial systems, dynamics and mechanics of biomolecules and multi-scale modeling and simulation of biophysical processes. Some problems make extensive use of large-scale computation, while others are more concerned with mathematical analysis. Most students actually become involved with both approaches during the course of their research.

Courses

Lower Division Courses

1A. General Chemistry. (4) Students will receive no credit for 1A after taking 4A. Three hours of lecture and four hours of laboratory per week. *Prerequisite: High school chemistry recommended.* Stoichiometry of chemical reactions, quantum mehanical description of atoms, the elements and the periodic table, chemical bonding, real and ideal gases, thermochemistry, introduction to thermodynamics and equilibrium, acid-base and solubility equilibria, introduction to oxidation-reduction reactions. *(F, S)*

1B. General Chemistry. (4) Students will receive no credit for 1B after taking 4B. Two hours of lecture and four hours of laboratory per week. *Prerequisite: 1A or a score of 3, 4, or 5 on the Chemistry AP test.* Introduction to chemical kinetics, electrochemistry, properties of the states of matter, binary mixtures, thermodynamic efficiency and the direction of chemical change, quantum mechanical description of bonding, introduction to spectroscopy. Special topics: Research topics in modern chemistry and biochemistry, chemical engineering. *(S)*

3A. Chemical Structure and Reactivity. (3) Students will receive no credit for 3A after taking 112A. Three hours of lecture per week. *Prerequisite: 1A with a grade of C- or higher, or a score of 4 or 5 on the Chemistry AP test. Concurrent enrollment in 3AL required.* Introduction to organic chemical structures, bonding, and chemical reactivity. The organic chemistry of alkanes, alkyl halides, alcohols, alkenes, alkynes, and organometallics. *(F, S)*

3AL. Organic Chemistry Laboratory. (2) Students will receive no credit for 3AL after taking 112A. One hour of lecture and four hours of laboratory per week. *Prerequisite: 1A with a grade of C- or higher, or a score of 4 or 5 on the Chemistry AP test. Must be taken concurrently with 3A.* Introduction to the theory and practice of methods used in the organic chemistry laboratory. An emphasis is placed on the separation and purification of organic compounds. Techniques covered will include extraction, distillation, sublimation, recrystallization, and chromatography. Detailed discussions and applications of infrared and nuclear magnetic resonance spectroscopy will be included. *(F, S)*

3B. Chemical Structure and Reactivity. (3) Students will receive no credit for 3B after taking 112B. Three hours of lecture per week. *Prerequisite: 3A with a grade of C- or better.* Conjugation, aromatic chemistry, carbonyl compounds, carbohydrates, amines, carboxylic acids, amino acids, peptides, proteins, and nucleic acid chemistry. Ultraviolet spectroscopy and mass spectrometry will be introduced. *(F, S)*

3BL. Organic Chemistry Laboratory. (2) Students will receive no credit for 3BL after taking 112B. One hour of lecture and four hours of laboratory per week. *Prerequisites: 3AL; 3B (may be taken concurrently).* The synthesis and purification of organic compounds will be explored. Natural product chemistry will be introduced. Advanced spectroscopic methods including infrared, ultraviolet, and nuclear magnetic resonance spectroscopy and mass spectrometry will be used to analyze products prepared and/or isolated. Qualitative analysis of organic compounds will be covered. *(F, S)*

4A-4B. General Chemistry and Quantitative Analysis. (4;4) Students will receive no credit for 4A after taking 1A. Students will receive no credit for 4B after taking 1B. Students will receive three units of credit for 4B after taking 15. Three hours of lecture and four hours of laboratory per week. *Prerequisites: High school chemistry; calculus (may be taken concurrently); high school physics is recommended.* The series 4A-4B is intended for majors in engineering and physical and biological sciences. It presents the foundation principles of chemistry, including stoichiometry, ideal and real gases, acid-base and solubility equilibria, oxidation-reduction reactions, thermochemistry, entropy, nuclear chemistry and radioactivity, the atoms and elements, the periodic table, quantum theory, chemical bonding, molecular structure, chemical kinetics, and descriptive chemistry. Examples and applications will be drawn from diverse areas of special interest such as atmospheric, environmental, materials, polymer and computational chemistry and biochemistry. Laboratory emphasizes quantitative work. Equivalent to 1A-1B plus 15 as prerequisite for further courses in chemistry. *4A (F); 4B (S)*

10. Chemical Attractions. (3) For nonscience majors. Three hours of lecture and one hour of discussion per week. The principles of chemistry permeate everything in the world around us. From the protection of sunscreens and the seductiveness of perfumes to the processes of DNA fingerprinting and art restoration to the foods and pharmaceuticals we ingest, chemistry is a crucial player in improving the quality of our lives. This course will introduce the nonscience major to chemical principles by exploring various "themes" such as perfumes and chemical communication, pesticides and the environment, diet and exercise, drugs and blood chemistry, art restoration, criminology, and plastics. In lieu of traditional problem sets and laboratories common in chemistry courses, students will prepare critiques of science as it is presented in the media, participate in solving a mock crime, and stage debates about the risks and benefits of chemistry. The course will culminate with group projects whereby students pursue a question or "theme" of their own interest.

15. Analytical and Bioanalytical Chemistry. (3) Students will receive two units of credit for 15 after taking 4B. Two hours of lecture and four hours of laboratory per week. *Prerequisite: 1A or equivalent.* An introduction to analytical and bioanalytical chemistry including background in statistical analysis of data, acid-base equilibria, electroanalytical potentiometry, spectrometric and chromatographic methods of analysis and some advanced topics in bioanalytical chemistry such as micro-fluidics, bioassay techniques, and enzymatic biosensors. *(F)*

24. Freshman Seminar. (1) Course may be repeated for credit as topic varies. One hour of seminar per week. Sections 1-2 to be graded on a letter-grade basis. Sections 3-4 to be graded on a *passed/not passed* basis. The Freshman Seminar Program has been designed to provide new students with the opportunity to explore an intellectual topic with a faculty member in a small-seminar setting. Freshman seminars are offered in all campus departments, and topics may vary from department to department and semester to semester. Enrollment is limited to 15 freshmen.

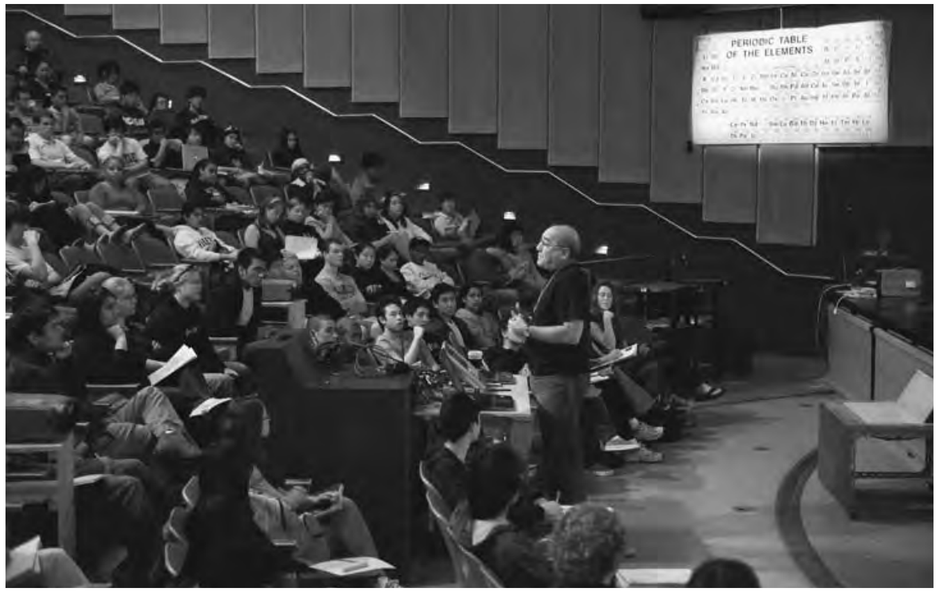
49. Supplementary Work in Lower Division Chemistry. (1-4) Course may be repeated for credit. Meetings to be arranged. Students with partial credit in lower division Chemistry courses may, with consent of instructor, complete the credit under this heading.

84. Sophomore Seminar. (1-2) One hour of seminar per week per unit for 15 weeks. One and one-half hours of seminar per week per unit for 10 weeks. Two hours of seminar per week per unit for eight weeks. Three hours of seminar per week per unit for five weeks. Sections 1-2 to be graded on a *passed/not passed* basis. Sections 3-4 to be graded on a letter-grade basis. *Prerequisites: At discretion of instructor.* Sophomore seminars are small interactive courses offered by faculty members in departments all across the campus. Sophomore seminars offer opportunity for close, regular intellectual contact between faculty members and students in the crucial second year. The topics vary from department to department and semester to semester. Enrollment limited to 15 sophomores. May be repeated for credit as topic varies.

C96. Introduction to Research and Study in the College of Chemistry. (1) One hour of seminar per week. Must be taken on a *passed/ not passed* basis. *Prerequisites: Freshman standing in chemistry, chemical biology, or chemical engineering major, or consent of instructor. Chemistry and chemical biology majors enroll in Chemistry C96 and chemical engineering majors enroll in Chemical Engineering C96.* Introduces freshmen to research activities and programs of study in the College of Chemistry. Includes lectures by faculty, an introduction to college library and computer facilities, the opportunity to meet alumni and advanced undergraduates in an informal atmosphere, and discussion of college and campus resources. Also listed as Chemical Engineering C96. *(F)*

98. Supervised Group Study. (1-4) Enrollment is restricted; see the "Introduction to Courses and Curricula" section of the *General Catalog*. One hour of work per week per unit. Must be taken on a *passed/not passed* basis. *Prerequisite: Consent of instructor.* Group study of selected topics.

98B. Issues in Chemistry. (1) Course may be repeated for credit as topic varies. One hour of seminar per week. Must be taken on a *passed/ not passed* basis. *Prerequisite: Score of 3, 4 or 5 on the Chemistry AP test, or 1A or 4A (may be taken concurrently).* This seminar will focus on one or several related issues in society that have a significant chemical component. Particular topics will differ between sections of the course and from year to year. Representative examples: atmospheric ozone, nuclear waste, solar energy, water, agrichemicals. Students will search information sources, invite expert specialists, and prepare oral and written reports.



98W. Directed Group Study. (1) Course may be repeated for credit. Must be taken on a *passed/not passed* basis. Topics vary with instructor. Enrollment restrictions apply. *(F, S)*

Upper Division Courses

100. Communicating Chemistry. (2) *Formerly 20.* Course may be repeated for credit. Two hours of lecture and one hour of fieldwork per week. For undergraduate and graduate students interested in improving their ability to communicate their scientific knowledge by teaching chemistry in elementary schools. The course will combine instruction in inquiry-based chemistry teaching methods and learning pedagogy with 10 weeks of supervised teaching experience in a local school classroom. Thus, students will practice communicating scientific knowledge and receive mentoring on how to improve their presentations. Approximately three hours per week, including time spent in school classrooms. *(S)*

103. Inorganic Chemistry in Living Systems. (3) Students will receive two units of credit for 103 after taking 104B. Three hours of lecture per week. *Prerequisite: 4B or 1B.* The basic principles of metal ions and coordination chemistry applied to the study of biological systems. *(F)*

104A-104B. Advanced Inorganic Chemistry. (3;3) Students will receive two units of credit for 104B after taking 103. Three hours of lecture per week. *Prerequisites: 104A: 1B, 4B, or 3A. 104B: 104A or consent of instructor.* The chemistry of metals and nonmetals including the application of physical chemical principles. *104A (F); 104B (S)*

105. Instrumental Methods in Analytical Chemistry. (4) Two hours of lecture and two four-hour laboratories per week. *Prerequisite: 4B; or 1B and 15; or 1B and a UC Berkeley GPA of 3.3 or higher.* Principles, instrumentation, and analytical applications of atomic spectroscopies, mass spectrometry, separations, electrochemistry, and micro-characterization. Discussion of instrument design and capabilities as well as real-world problem solving with an emphasis on bioanalytical, environmental, and forensic applications. Hands-on laboratory work using modern instrumentation, emphasizing independent projects involving real-life samples and problem solving. *(F, S)*

108. Inorganic Synthesis and Reactions. (4) Two hours of lecture and eight hours of laboratory per week. *Prerequisites: 4B or 15; 104A with a grade of C- or higher; 104B (may be taken concurrently).* The preparation of inorganic compounds using vacuum line, air- and moisture-exclusion, electrochemical, high-pressure, and other synthetic techniques. Kinetic and mechanistic studies of inorganic compounds. *(F, S)*

112A-112B. Organic Chemistry. (5;5) Students will receive no credit for 112A after taking 3A and 3AL. Students will receive no credit for 112B after taking both 3B and 3BL. Students will receive two units of credit for 112B after taking 3B (lecture only). Three hours of lecture, one hour of laboratory discussion, and five hours of laboratory per week. *Prerequisite: 112A: 1B or 4B with a grade of C- or higher. 112B: 112A with a grade of C- or higher. For students majoring in chemistry, chemical biology, or a closely related field such as chemical engineering or molecular and cell biology.* A study of all aspects of fundamental organic chemistry, including nomenclature, chemical and physical properties, reactions and syntheses of the major classes of organic compounds. The study includes theoretical aspects, reaction mechanisms, multistep syntheses and the chemistry of polycyclic and heterocyclic compounds. This course is more extensive and intensive than 3A-3B and includes a greater emphasis on reaction mechanisms and multistep syntheses. *112A (F); 112B (S)*

113. Advanced Mechanistic Organic Chemistry. (3) Three hours of lecture per week. *Prerequisite: 3B or 112B with a minimum grade of B-, or consent of instructor.* Advanced topics in mechanistic and physical organic chemistry, typically including kinetics, reactive intermediates, substitution reactions, linear free energy relationships, orbital interactions and orbital symmetry control of reactions, isotope effects, and photochemistry. Offered alternate years. *(F)*

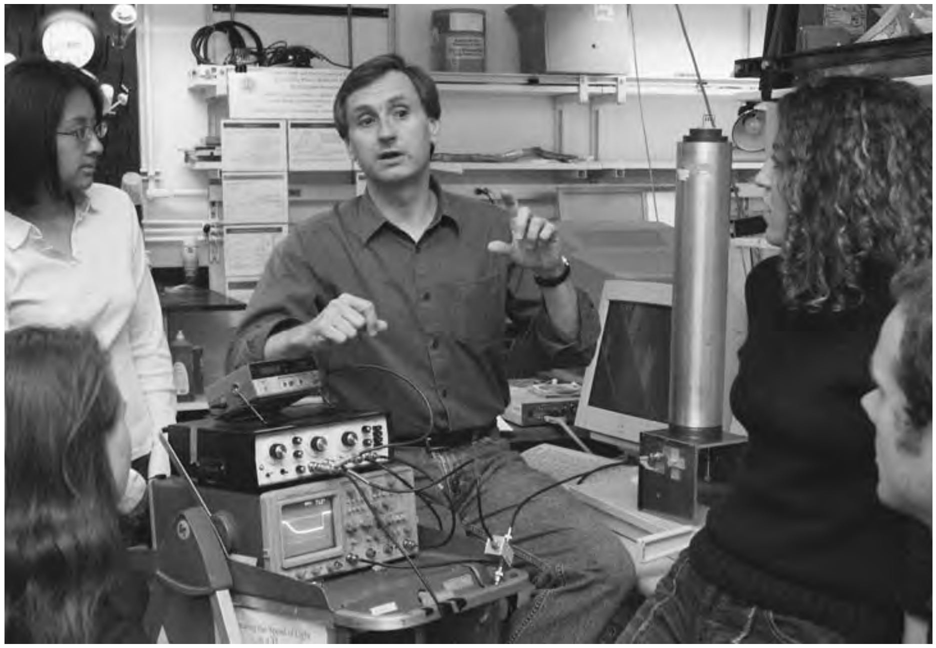
114. Advanced Synthetic Organic Chemistry. (3) Three hours of lecture per week. *Prerequisite: 3B or 112B with a minimum grade of B-, or consent of instructor.* Advanced topics in synthetic organic chemistry with a focus on selectivity. Topics include reductions, oxidations, enolate chemistry and the aldol reaction, reactions of nonstabilized anions, olefination reactions, pericyclic reactions, and application to the synthesis of complex structures. Offered alternate years. *(S)*

115. Organic Chemistry — Advanced Laboratory Methods. (4) One hour of lecture and 11 hours of laboratory per week. *Prerequisite: 112B with a grade of C- or higher.* Advanced synthetic methods, chemical and spectroscopic structural methods, designed as a preparation for experimental research. *(F, S)*

120A. Physical Chemistry. (3) Students will receive two units of credit for 120A after taking 130B. Three hours of lecture per week. *Prerequisites: 4B or equivalent; Math 53; Physics 7B or 8B; Math 54 (may be taken concurrently).* Kinetic, potential, and total energy of particles and forces between them; principles of quantum theory, including one-electron and many-electron atoms. The course will be divided (fall semester) into a section for chemistry majors and one for chemical biology majors, both meeting at the same time, covering topics of interest to each group relating to molecules and chemical bonding, electrical properties, intermolecular interactions, and elementary spectroscopy. *(F, S)*

120B. Physical Chemistry. (3) Students will receive two units of credit for 120B after taking C130 or Molecular and Cell Biology C100A. Three hours of lecture per week. *Prerequisites: 4B or equivalent; Math 53; Physics 7B or 8B; Math 54 (may be taken concurrently)*. Statistical mechanics, thermodynamics, and equilibrium. The course will be divided (spring semester) into a section for chemistry majors and one for chemical biology majors, both meeting at the same time, covering topics of interest to each group relating to states of matter, solutions and solvation, (bio)chemical kinetics, molecular dynamics, physical characterization, and transport of molecules. *(F, S)*

122. Quantum Mechanics and Spectroscopy. (3) Three hours of lecture per week. *Prerequisite: 120A.* Postulates and methods of quantum mechanics and group theory applied to molecular structure and spectra.



125. Physical Chemistry Laboratory. (3) Students will receive one unit of credit for 125 after taking C182 or Earth and Planetary Science C182. Instructor's approval is required to enroll in 125 after completing C182 or EPS C182. One hour of lecture and one five-hour laboratory per week. *Prerequisites: Two of the following: 120A, 120B, C130, or 130B with grades of C- or higher (one of which may be taken concurrently).* Experiments in thermodynamics, kinetics, molecular structure, and general physical chemistry. *(F, S)*

C130. Biophysical Chemistry: Physical Principles and the Molecules of Life. (4) Students will receive three units of credit for C130 after taking 120B. Three hours of lecture and one hour of discussion per week. *Prerequisites: Math 1A; Biology 1A and 1AL; Chemistry 3A or 112A; Chemistry 3B or 112B recommended.* Thermodynamic and kinetic concepts applied to understanding the chemistry and structure of biomolecules (proteins, DNA, and RNA). Molecular distributions, reaction kinetics, enzyme kinetics. Bioenergetics, energy transduction, and motor proteins. Electro-chemical potential, membranes, and ion channels. Also listed as MCB C100A. *(F, S)*

130B. Biophysical Chemistry. (3) Students will receive no credit for 130B after taking both 120A and 120B. Students will receive two units of credit for 130B after taking either 120A or 120B. Two hours of lecture and one hour of discussion per week. *Prerequisite: C130 or MCB C100A or consent of instructor.* The weekly one-hour discussion is for problem solving and the application of calculus in physical chemistry. Molecular structure, intermolecular forces and interactions, biomolecular spectroscopy, high-resolution structure determinations. *(S)*

135. Chemical Biology. (3) Three hours of lecture per week. *Prerequisites: 3B or 112B; Biology 1A; or consent of instructor.* One-semester introduction to biochemistry, aimed toward chemistry majors. *(F, S)*

143. Nuclear Chemistry. (2) Two hours of lecture per week. *Prerequisite: Physics 7B or equivalent.* Radioactivity, fission, nuclear models and reactions, nuclear processes in nature. Computer methods will be introduced. *(F)*

146. Chemical Methods in Nuclear Technology. (3) One one-and-a-half-hour lecture and one four-and-a-half-hour laboratory per week. *Prerequisites: 4B or 15; 143 is recommended.* Experimental illustrations of the interrelation between chemical and nuclear science and technology; fission process, chemistry of fission fragments, chemical effects of nuclear transformation; application of radioactivity to study of chemical problems; neutron activation analysis. *(S)*

149. Supplementary Work in Upper Division Chemistry. (1-4) Course may be repeated for credit. Meetings to be arranged. Students with partial credit in upper division chemistry courses may, with consent of instructor, complete the credit under this heading.

C150. Introduction to Materials Chemistry. (3) Three hours of lecture per week. *Prerequisite: 104B is recommended.* The application of basic chemical principles to problems in materials discovery, design, and characterization will be discussed. Topics covered will include inorganic solids, nanoscale materials, polymers, and biological materials, with specific focus on the ways in which atomic-level interactions dictate the bulk properties of matter. Also listed as Materials Science and Engineering C150. *(S)*

C170L. Biochemical Engineering Laboratory. (3) One hour of lecture and six hours of laboratory per week. *Prerequisite: Chemical Engineering 170A (may be taken concurrently) or consent of instructor.* Laboratory techniques for the cultivation of microorganisms in batch and continuous reactions. Enzymatic conversion processes. Recovery of biological products. Also listed as Chemical Engineering C170L. *(S)*

C178. Polymer Science and Technology. (3) Three hours of lecture/laboratory per week. *Prerequisites: One semester of organic chemistry and physics recommended; Chemical Engineering 150A, equivalent fluid mechanics, or consent of instructor.* Introduction to physical and chemical behavior of organic polymers. Properties of solutions, melts, glasses, elastomers, and crystals. Engineering applications emphasizing processing technology. Experiments in polymerization and characterization. Also listed as Chemical Engineering C178. *(F)*

C182. Atmospheric Chemistry and Physics Laboratory. (3) Students will receive one unit of credit for C182 after taking 125. Instructor's approval is required to enroll in C182 after completing 125. One hour of lecture and five hours of laboratory per week. *Prerequisites: College-level calculus, chemistry and physics, or consent of instructor.* Fluid dynamics, radiative transfer, and the kinetics, spectroscopy, and measurement of atmospherically relevant species are explored through laboratory experiments, numerical simulations, and field observations. The course is intended for Earth and Planetary Science majors and minors, and for chemistry, physics, astronomy, biology, and engineering majors whose interests may lie in science applied to the atmosphere of Earth and other planets. Also listed as Earth and Planetary Science C182. *(S)*

C191. Quantum Information Science and Technology. (3) Three hours of lecture and one hour of discussion per week. *Prerequisites: Math 54; Physics 7A; Physics 7B; and either Physics 7C, Math 55, or Computer Science 170 are required.* This multidisciplinary course provides an introduction to fundamental conceptual aspects of quantum mechanics from a computational and informational theoretic perspective, as well as physical implementations and technological applications of quantum information science. Basic sections of quantum algorithms, complexity, and cryptography will be touched upon, as well as pertinent physical realizations from nanoscale science and engineering. Also listed as Computer Science C191 and Physics C191. *(F)*

192. Individual Study for Advanced Undergraduates. (1-3) Course may be repeated for credit. Individual conferences. *Prerequisites: Consent of instructor and adviser.* All properly qualified students who wish to pursue a problem of their own choice, through reading or nonlaboratory study, may do so if their proposed project is acceptable to the member of the staff with whom they wish to work. *(F, S)*

H194. Research for Advanced Undergraduates. (2-4) Course may be repeated for credit. Minimum of three hours of work per week per unit of credit. *Prerequisites: Minimum GPA of 3.4 overall at Berkeley and consent of instructor and adviser.* Students may pursue original research under the direction of one of the members of the staff. *(F, S)*

195. Special Topics. (3) Course may be repeated for credit. Three hours of lecture per week. *Prerequisite: Consent of instructor.* Special topics will be offered from time to time. Examples are photochemical air pollution, computers in chemistry.

196. Special Laboratory Study. (2-4) Course may be repeated for credit. Laboratory. *Prerequisites: Consent of instructor and adviser.* Special laboratory work for advanced undergraduates. *(F, S)*

197. Field Study in Chemistry. (1-4) Course may be repeated for credit. Three hours of field work per week per unit. Must be taken on a *passed/not passed* basis. *Prerequisites: Upper division standing and consent of instructor.* Supervised experience in off-campus organizations relevant to specific aspects and applications of chemistry. Written report required at the end of the term. This course does not satisfy unit or residence requirements for the bachelor's degree. *(F, S)*

198. Directed Group Study. (1-4) One hour of class per week per unit. Course may be repeated for credit. Must be taken on a *passed/not passed* basis. *Prerequisites: Completion of 60 units of undergraduate study and in good academic standing.* Group study of selected topics. Enrollment is restricted; see the "Introduction to Courses and Curricula" section of the *General Catalog.*

199. Supervised Independent Study and Research. (1-4) Course may be repeated for credit. Must be taken on a *passed/not passed* basis. Nonlaboratory study only. Enrollment is restricted by regulations listed in the *General Catalog. (F, S)*

Graduate Courses

200. Chemistry Fundamentals. (1) Three hours of lecture per week for five weeks. *Prerequisite: Graduate standing or consent of instructor.* Review of bonding, structure, stereo-chemistry, conformation, thermodynamics and kinetics, and arrow-pushing formalisms. *(F)*

201. Fundamentals of Inorganic Chemistry. (1) Three hours of lecture per week for five weeks. *Prerequisite: Graduate standing or consent of instructor.* Review of bonding, structure, MO theory, thermodynamics, and kinetics. *(F)*

208. Structure Analysis by X-Ray Diffraction. (4) Two one-hour lectures and two four-hour laboratories per week. *Prerequisite: Consent of instructor.* The theory and practice of modern, single-crystal X-ray diffraction. Groups of four students determine the crystal and molecular structure of newly synthesized materials from the College of Chemistry. The laboratory work involves the mounting of crystals and initial evaluation by X-ray diffraction film techniques, the collection of intensity data by automated diffractometer procedures, and structure analysis and refinement. *(S)*

220A. Thermodynamics and Statistical Mechanics. (3) Three one-hour lectures per week. *Prerequisite: 120B.* A rigorous presentation of classical thermodynamics followed by an introduction to statistical mechanics with the application to real systems. *(F)*

220B. Statistical Mechanics. (3) Three one-hour lectures per week. *Prerequisite: 220A.* Principles of statistical mechanics and applications to complex systems. *(S)*

221A. Advanced Quantum Mechanics. (3) Three hours of lecture per week. *Prerequisites: 120B and 122 or equivalent.* Introduction, one dimensional problems, matrix mechanics, approximation methods. *(F)*

221B. Advanced Quantum Mechanics. (3) Three hours of lecture per week. *Prerequisite: 221A.* Time dependence, interaction of matter with radiation, scattering theory. Molecular and many-body quantum mechanics. *(S)*

222. Spectroscopy. (3) Three hours of lecture per week. *Prerequisite: Graduate standing or consent of instructor.* The course presents a survey of experimental and theoretical methods of spectroscopy, and group theory as used in modern chemical research. The course topics include experimental methods, classical and quantum descriptions of the interaction of radiation and matter. Qualitative and quantitative aspects of the subject are illustrated with examples including application of linear and nonlinear spectroscopies to the study of molecular structure and dynamics and to quantitative analysis. This course is offered jointly with 122. *(S)*

223A. Chemical Kinetics. (3) Three hours of lecture per week. *Prerequisite: 220A (may be taken concurrently).* Deduction of mechanisms of complex reactions. Collision and transition state theory. Potential energy surfaces. Unimolecular reaction rate theory. Molecular beam scattering studies. *(S)*

223B. Chemical Dynamics. (3) Three hours of lecture per week. *Prerequisites: 221A, 223A.* Quantum mechanical scattering theory of elastic, inelastic, and reactive collisions. Electronically non-adiabatic processes. Collision complexes and scattering resonances. Semiclassical scattering theory for molecular collision. Generalized statistical models for chemical reactions. *(F)*

C230. Protein Chemistry, Enzymology, and Bio-organic Chemistry. (2) Three hours of lecture per week for ten weeks. *Prerequisite: Graduate standing or consent of instructor.* The topics covered will be chosen from the following: protein structure; protein-protein interactions; enzyme kinetics and mechanism; enzyme design. Intended for graduate students in chemistry, biochemistry, and molecular and cell biology. Also listed as MCB C214.

243. Advanced Nuclear Structure and Reactions. (3) Three hours of lecture per week. *Prerequisites: 143 or equivalent and introductory quantum mechanics.* Selected topics on nuclear structure and nuclear reactions.

250A. Introduction to Bonding Theory. (1) Three hours of lecture per week for five weeks. *Prerequisites: 200 or 201 or consent of instructor and background in the use of matrices and linear algebra.* An introduction to group theory, symmetry, and representations as applied to chemical bonding. *(F)*

250B. Inorganic Spectroscopy. (1) Three hours of lecture per week for five weeks. *Prerequisite: 250A or consent of instructor.* The theory of vibrational analysis and spectroscopy as applied to inorganic compounds. *(S)*

251A. Coordination Chemistry I. (1) Three hours of lecture per week for five weeks. *Prerequisite: 250A or consent of instructor.* Structure and bonding, synthesis, and reactions of the d-transition metals and their compounds. *(F)*

251B. Coordination Chemistry II. (1) Three hours of lecture per week for five weeks. *Prerequisite: 251A or consent of instructor.* Synthesis, structure analysis, and reactivity patterns in terms of symmetry orbitals.

252A. Organometallic Chemistry I. (1) Three hours of lecture per week for five weeks. *Prerequisite: 200 or 201 or consent of instructor.* An introduction to organometallics, focusing on structure, bonding, and reactivity. *(F)*

252B. Organometallic Chemistry II. (1) Three hours of lecture per week for five weeks. *Prerequisite: 252A or consent of instructor.* Applications of organometallic compounds in synthesis with an emphasis on catalysis. *(F)*

253A. Materials Chemistry I. (1) Three hours of lecture per week for five weeks. *Prerequisites: 200 or 201, and 250A, or consent of instructor.* Introduction to the descriptive crystal chemistry and electronic band structures of extended solids.

253B. Materials Chemistry II. (1) Three hours of lecture per week for five weeks. *Prerequisite: 253A or consent of instructor.* General solid-state synthesis and characterization techniques as well as a survey of important physical phenomena including optical, electrical, and magnetic properties.

253C. Materials Chemistry III. (1) Three hours of lecture per week for five weeks. *Prerequisite: 253A or consent of instructor.* Introduction to surface, catalysis, organic solids, nanoscience. Thermodynamics and kinetics of solid-state diffusion and reaction will be covered.

254. Bioinorganic Chemistry. (1) Three hours of lecture per week for five weeks. A survey of the roles of metals in biology, taught as a tutorial involving class presentations. *(S)*

256. Electrochemical Methods. (1) Three hours of lecture per week for five weeks. The effect of structure and kinetics on the appearance of cyclic voltammograms and the use of cyclic voltammetry to probe the thermodynamics, kinetics, and mechanisms of electrochemical reactions.

260. Reaction Mechanisms. (2) *Formerly 260A-260B.* Three hours of lecture and in-class discussion and problem solving for 10 weeks and one week of computer laboratory. *Prerequisite: 200 or 201 or consent of instructor.* Advanced methods for studying organic reaction mechanisms. Topics include kinetic isotope effects, behavior of reactive intermediates, chain reactions, concerted reactions, molecular orbital theory and aromaticity, solvent and substituent effects, linear free energy relationships, photochemistry. *(F)*

261A. Organic Reactions I. (1) Three hours of lecture per week for five weeks. *Prerequisite: 200 or 201 or consent of instructor.* Features of the reactions that comprise the vocabulary of synthetic organic chemistry. *(F)*

261B. Organic Reactions II. (1) Three hours of lecture per week for five weeks. *Prerequisite: 261A or consent of instructor.* More reactions that are useful to the practice of synthetic organic chemistry. *(F)*

261C. Organic Reactions III. (1) Three hours of lecture per week for five weeks. *Prerequisite: 261B or consent of instructor.* This course will consider further reactions with an emphasis on pericyclic reactions such as cycloadditions, electrocyclizations, and sigmatropic rearrangements. *(F)*

262. Metals in Organic Synthesis. (1) Three hours of lecture per week for five weeks. *Prerequisite: 261B or consent of instructor.* Transition metal-mediated reactions occupy a central role in asymmetric catalysis and the synthesis of complex molecules. This course will describe the general principles of transition metal reactivity, coordination chemistry, and stereoselection. This module will also emphasize useful methods for the analysis of these reactions. *(S)*

263A. Synthetic Design I. (1) Three hours of lecture per week for five weeks. *Prerequisite: 262 or consent of instructor.* This course will describe the application of modern reactions to the total synthesis of complex target molecules. Natural products, such as alkaloids, terpenes, or polypropionates, as well as theoretically interesting “non-natural” molecules will be covered. *(S)*

263B. Synthetic Design II. (1) Three hours of lecture per week for five weeks. *Prerequisite: 263A or consent of instructor.* The principles of retrosynthetic analysis will be laid down and the chemistry of protecting groups will be discussed. Special attention will be given to the automated synthesis of biopolymers such as carbohydrates, peptides, and proteins, as well as nucleic acids.

264A. Synthesis of Macromolecules. (1) Three hours of lecture per week for five weeks. *Prerequisite: 200 or consent of instructor.* The concepts of chain-growth and step-growth polymerizations. Radical, ionic, and metal catalyzed polymerizations. Living polymerization. Controlling macromolecular architecture: dendrimers, hyperbranced polymers, and cross-linked networks.

264B. Properties and Applications of Macromolecules. (1) Three hours of lecture per week for five weeks. *Prerequisite: 264A or consent of instructor*. Characterization of macromolecules. Structure-property relationships. Specialty polymers and their applications: polymers in therapeutics, biomedical polymers and implants, conducting polymers, polymers in microelectronics and photonics, polymers in separation and molecular recognition, supramolecular chemistry, and self-assembly.

265. Nuclear Magnetic Resonance Theory and Application. (1) Three hours of lecture per week for five weeks. *Prerequisite: 200 or 201 or consent of instructor.* The theory behind practical nuclear magnetic resonance spectroscopy and a survey of its applications to chemical research. *(S)*

266. Mass Spectrometry. (1) Three hours of lecture per week for five weeks. *Prerequisite: 200 or 201 or consent of instructor.* Basic mass spectrometric ionization techniques and analyzers as well as simple fragmentation mechanisms for organic molecules; methods for analyzing organic and inorganic samples, along with an opportunity to be trained and checked out on several open-access mass spectrometers; in-depth instruction on the use of mass spectrometry for the analysis of biomolecules such as proteins, peptides, carbohydrates, and nucleic acids.

267. Organic Specialties. (1) Three hours of lecture per week for five weeks. *Prerequisite: Graduate-level understanding of organic synthesis or consent of instructor.* A survey course focusing on an area of organic chemistry of importance, such as pharmaceutical chemistry, combinatorial chemistry, natural products chemistry, etc.

268. Mass Spectrometry. (2) Course 266 will restrict credit if completed before 268. Three hours of lecture per week for 10 weeks. *Prerequisite: Graduate standing or consent of instructor.* Principles, instrumentation, and applications in mass spectrometry, including ionization methods, mass analyzers, spectral interpretation, multidimensional methods (GC/MS, HPLC/MS, MS/MS), with emphasis on small organic molecules and bioanalytical applications (proteins, peptides, nucleic acids, carbohydrates, noncovalent complexes); this will include the opportunity to be trained and checked out on several open-access mass spectrometers. *(S)*

270A. Advanced Biophysical Chemistry I. (1) Two hours of lecture per week for seven and one-half weeks. *Prerequisite: 200 or consent of instructor.* Underlying principles and applications of methods for biophysical analysis of biological macromolecules. *(F)*

270B. Advanced Biophysical Chemistry II. (1) Two hours of lecture per week for seven and one-half weeks. *Prerequisite: 270A or consent of instructor.* More applications of methods for biophysical analysis of biological macromolecules. *(F)*

271A. Chemical Biology I: Structure, Synthesis, and Function of Biomolecules. (1) Three hours of lecture per week for five weeks. *Prerequisite: 200 or consent of instructor.* This course will present the structure of proteins, nucleic acids, and oligosaccarides from the perspective of organic chemistry. Modern methods for the synthesis and purification of these molecules will also be presented. *(S)*

271B. Chemical Biology II: Enzyme Reaction Mechanisms. (1) Three hours of lecture per week for five weeks. *Prerequisite: 271A or consent of instructor.* The course will focus on the principles of enzyme catalysis. The course will begin with an introduction to the general concepts of enzyme catalysis, which will be followed by detailed examples that will examine the chemistry behind the reactions and the three-dimensional structures that carry out the transformations. *(S)*

271C. Chemical Biology III: Contemporary Topics in Chemical Biology. (1) Three hours of lecture per week for five weeks. *Prerequisite: 271B or consent of instructor.* This course will build on the principles discussed in Chemical Biology I and II. The focus will consist of case studies where rigorous chemical approaches have been brought to bear on biological questions. Potential subject areas will include signal transduction, photosynthesis, immunology, virology, and cancer. For each topic, the appropriate bioanalytical techniques will be emphasized. *(S)*

272A. Bio X-ray I. (1) Three hours of lecture per week for five weeks. *Prerequisite: 270A-270B or consent of instructor.* Theory and application of X-ray crystallography to biomacromolecules. *(S)*

272B. Bio X-Ray II. (1) Three hours of lecture per week for five weeks. *Prerequisite: 272A or consent of instructor.* More sophisticated aspects of the application of X-ray crystallography to biomacromolecules. *(S)*

273A. Bio NMR I. (1) Two hours of lecture per week for seven and one-half weeks. *Prerequisites: 270A-270B or consent of instructor.* Fundamentals of multidimensional NMR spectroscopy (including use of the density matrix for analysis of spin response to pulse sequences) and applications of multi-dimensional NMR in probing structure, interactions, and dynamics of biological molecules will be described.

273B. Bio NMR II. (1) Two hours of lecture per week for seven and one-half weeks. *Prerequisite: 273A.* Triple resonance methods for determination of protein and nucleic acid resonance assignments, and for generation of structural restraints (distances, angles, H-bonds, etc.). Methods for calculating biomolecular structures from NMR data and the quality of such structures will be discussed.

295. Special Topics. (1-3) Course may be repeated for credit. Must be taken on a *satisfactory/unsatisfactory* basis. *Prerequisite: Graduate standing or consent of instructor.* Lecture series on topics of current interest. Recently offered topics: Natural products synthesis, molecular dynamics, statistical mechanics, molecular spectroscopy, structural biophysics, organic polymers, electronic structure of molecules, and bio-organic chemistry. *(F, S)*

298. Seminars for Graduate Students. (1-3) Course may be repeated for credit. Must be taken on a *satisfactory/unsatisfactory* basis. Seminars. *Prerequisite: Graduate standing.* In addition to the weekly Graduate Research Conference and weekly seminars on topics of interest in biophysical, organic, physical, nuclear, and inorganic chemistry, there are group seminars on specific fields of research. Seminars will be announced at the beginning of each semester. *(F, S)*

299. Research for Graduate Students. (1-9) Course may be repeated for credit. Laboratory. *Prerequisite: Graduate standing.* The facilities of the laboratory are available at all times to graduate students pursuing original investigations toward an advanced degree at this University. Such work is ordinarily in collaboration with members of the staff. *(F, S)*

602. Individual Study for Doctoral Students. (1-8) Course may be repeated for credit. Must be taken on a *satisfactory/unsatisfactory* basis. Individual study in consultation with the major field adviser, intended to provide an opportunity for qualified students to prepare themselves for the various examinations required of candidates for the Ph.D. degree. May not be used for unit or residence requirements for the doctoral degree. *(F, S)*

Professional Courses

300. Professional Preparation: Supervised Teaching of Chemistry. (2) Course may be repeated for credit. *Prerequisites: Graduate standing and appointment as a graduate student instructor.* Discussion, curriculum development, class observation, and practice teaching in chemistry. *(F, S)*

301A. Undergraduate Laboratory Instruction. (2) Course may be repeated once for credit. Must be taken on a *passed/not passed* basis. One hour of lecture, four hours of tutoring during 1A-1B laboratories, and one office hour per week. *Prerequisites: Junior standing or instructor approval; completion of 1A-1B with a grade of B- or better.* Tutoring of students in 1A-1B laboratories. Students attend one hour of the regular GSI preparatory meeting and hold one office hour per week to answer questions about laboratory assignments. *(F, S)*

301B. Undergraduate Chemistry Instruction. (2) *Formerly 301.* Course may be repeated once for credit. Must be taken on a *passed/not passed* basis. One hour of lecture and five hours of tutoring per week. *Prerequisites: Sophomore standing; completion of 1A-1B with grade of B- or better.* Tutoring of students in 1A-1B. Students attend a weekly meeting on tutoring methods at the Student Learning Center and attend 1A-1B lectures. *(F, S)*

301C. Chemistry 3 Laboratory Assistant. (2) Course may be repeated once for credit. Must be taken on a *passed/not passed basis.* One hour of preparation meeting, four hours of instruction in the laboratory, and one hour of laboratory experiment preparation per week. *Prerequisites: Sophomore standing and consent of instructor; completion of Chemistry 3B with a grade of B or better.* Undergraduate organic laboratory assistants help in the teaching of the Chemistry 3A-3B laboratories. Each week students attend a laboratory preparation meeting for one hour, assist in the laboratory section for four hours, and help in the development of experiments for one hour. *(F, S)*

301T. Undergraduate Preparation for Teaching or Instruction in Teaching. (2) Course may be repeated for a maximum of eight units. Two or three hours of lecture and one hour of teacher training per week. *Prerequisites: Junior standing, overall GPA of 3.1 and consent of instructor. (F, S)*

301W. Supervised Instruction of Chemistry Scholars. (2) Course may be repeated for credit. Must be taken on a *passed/not passed* basis. One hour of lecture and three or four hours of tutoring per week. *Prerequisites: Sophomore standing and consent of instructor.* Tutoring of students in the College of Chemistry Scholars Program who are enrolled in general or organic chemistry. Students attend a weekly meeting with instructors.

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Robert J. Birgeneau, Ph.D.

Executive Vice Chancellor and Provost, Berkeley
George W. Breslauer, Ph.D.

Dean of the Graduate Division, Berkeley
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College of Chemistry Administration

Interim Dean
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Associate Dean (Undergraduate Affairs)
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Assistant Dean (Engineering and Facilities)
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Assistant Dean (College Relations)
Jane L. Scheiber

Assistant Dean (Finance and Administration)
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Harvey W. Blanch, Ph.D. *(The Merck Professor in Biochemical Engineering)*
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Michael C. Williams, Ph.D. *(Emeritus)*

Associate Professor
Alexander Katz, Ph.D.

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Jhih-Wei Chu, Ph.D.
Rachel A. Segalman, Ph.D. *(The Charles Wilke Professor)*

Adjunct Professors
Brian L. Maiorella, Ph.D.
David S. Soane, Ph.D.

Lecturers
Carlo Alesandrini, Ph.D.
Keith Alexander, Ph.D.
P. Henrik Wallman, Ph.D.
Xiao-Yan Wang, Ph.D.

Faculty of the Department of Chemistry

University Professors
Gabor A. Somorjai, Ph.D.
Yuan T. Lee, Ph.D. *(Emeritus)*

Professors
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John Arnold, Ph.D.
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Ronald C. Cohen, Ph.D. *(Earth and Planetary Science)*
Jennifer A. Doudna, Ph.D. *(Molecular and Cell Biology)*
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Jamie H. Doudna Cate, Ph.D. *(Molecular and Cell Biology)*
Matthew B. Francis, Ph.D.
Jay T. Groves, Ph.D.
Jeffrey R. Long, Ph.D.
F. Dean Toste, Ph.D.

Assistant Professors
Christopher J. Chang, Ph.D.
Michelle C. Chang, Ph.D. *(The Chevron Professor)*
Phillip L. Geissler, Ph.D.
Bryan A. Krantz, Ph.D. *(Molecular and Cell Biology)*
Richmond Sarpong, Ph.D.
Ting Xu, Ph.D. *(Materials Science and Engineering)*
Haw Yang, Ph.D.

Lecturers
Michelle Douskey, Ph.D.
Chunmei Li, Ph.D.
Steven Pedersen, Ph.D.
Neil L. Viernes, Ph.D.

College of Chemistry Breadth Requirement Course List

Group I (Reading and Composition)

Courses taken to satisfy Group I also satisfy the Reading and Composition requirement.

African American Studies
R1A-R1B. Freshman Composition (4-4)

Anthropology
R5B. Reading and Composition in Anthropology (4)

Asian American Studies
R2A-R2B. Reading and Composition (4-4)

Celtic Studies
R1A-R1B. Voices of the Celtic World (4-4)

Chicano Studies
R1AN. Reading and Composition (3)

College Writing Programs
R4A. Reading and Composition (4)
R4B. Reading, Composition, and Research (4)

Comparative Literature
R1A-R1B. English Composition in Connection with the Reading of World Literature (4-4)
H1A-H1B. English Composition in Connection with the Reading of World Literature (4-4)
R2A-R2B. English Composition in Connection with the Reading of World and French Literature (5-5)
R3A-R3B. English Composition in Connection with Reading of World and Hispanic Literature (5-5)

English
R1A-R1B. Reading and Composition (4-4)

Film Studies
R1A-R1B. The Craft of Writing — Film Focus (4-4)

French (taught in English)
R1A. English Composition in Connection with the Reading of Literature (4)

Gender and Women's Studies
R1B. Reading and Composition (4)

German (taught in English)
R5A-R5B. Reading and Composition (4-4)

History
R1. The Practice of History (4)

Note: Satisfies the second level of the Reading and Composition requirement

History of Art
R1B. Reading and Writing About Visual Experience (4)

Italian Studies (taught in English)
R5A-R5B. Italy at Home and Abroad (4-4)

Letters and Science
R44. Western Civilization (5)

Note: Satisfies either the first level or the second level of the Reading and Composition requirement

Native American Studies
R1A-R1B. Native American Studies Reading and Composition (4-4)

Near Eastern Studies (taught in English)
R1A-R1B. Reading and Composition in Ancient Near Eastern Texts (4-4)
R2A-R2B. Reading and Composition in Modern Middle Eastern Texts (4-4)

Rhetoric
R1A-R1B. The Craft of Writing (4-4)

Scandinavian (taught in English)
R5A-R5B. Reading and Composition (4-4)

Slavic (taught in English)
R5A-R5B. Writing and Reading About Russia (4-4)

South Asian (taught in English)
R5A. Great Books of India (4)
R5B. India in the Writer's Eye (4)

South and Southeast Asian Studies
R5A. Self, Representation, and Nation (4)
R5B. Under Western Eyes (4)

Theater, Dance, and Performance Studies
R1A-R1B. Introduction to Dramatic Literature (4-4)

College Writing R1A with a grade of C- or better satisfies the Entry-Level Writing requirement and the first level of the Reading and Composition requirement. Only four units (of the six) are accepted toward the Breadth requirement.

The following writing-intensive courses are considered equivalent to English R1B: Linguistics R6 plus a corequisite Linguistics course (5 to 6 units total); Slavic R37W (5 units); and Gender and Women's Studies R20W (5 units).

Group II (Humanities and Social Sciences)

Department headings marked "any" indicate that all undergraduate courses in that department are acceptable for breadth credit, provided that they are at least two-unit courses. Exception: In general, courses numbered 98, 99, or above 190 are not acceptable for breadth credit.

Note: A course used toward satisfaction of the Breadth requirement cannot also be used toward satisfaction of another college or major requirement (such as an allied subject or a science or engineering elective). This restriction does not apply to the University and Berkeley campus requirements of American History and Institutions and American Cultures.

Please see notes at the end of this list for additional information and restrictions.

Aerospace Studies
2A and 2B

Note: To count toward satisfaction of the Breadth requirement, both 2A and 2B must be completed.

African American Studies
4A-29AC, 100-117, 121-138, 139*, 142A-163, C178

Afrikaans
10, 150

American Studies
10-30AC, 101, 101AC, 102, 110*, C115, C117, 118AC, C136, 139AC, C152, C169A-C169B, C172, C174, C177, 180C

Anthropology
2, 3, 3AC, 10AC-18, 72-74, 94, 106, 109, 111, 114-119, 121A-C, 122A-122F, 123A-123E, 124A, 124AC, C125B, 128-130, 132, 133, 134, 136-166, 169B-171, 172AC, 173, 174AC-189

Arabic
1A, 1B, 15A, 15B, 20A, 20B, 100A, 100B, 104A, 104B, 105A, 105B, 108, 111A, 111B, 120A, 120B, 148

Architecture
100A, 100B, 101, 102, 105, 109, 110, 118AC, C119, 120, 135, 139, 170A, 170B, 172, 173A, 173B, 174A, 174B, 174C, 175A, 175B, 175C

Art, History of
any, except R1B, N142

Asian American Studies
20A-20C, 120-190

Asian Studies
10, 147, 148, 149, 150

Buddhist Studies
C50, C114, C115, C120, C122, C124, C126, C128, C130, C140, C174

Business Administration (UGBA)
10, 39AC, 112, 150, 154, 155, 156, 170, 171, C172, 175, 187, 188

Catalan
101, 102

Celtic Studies
15, 16, 70, 85, 86, 102A, 102B, 105A, 105B, 106C, 116B, 118A, 118B, 119A, 119B, 125, 126, 128, 129, 138, 139, 144A, 144B, 145A, 145B, 146A, 146B, 161, C168, 169, 173

Chicano Studies
6A, 6B, 20, 40, 50, 70, 80, 101, 130, 133, 135, 141, 142, 143, 145, 148, 149, 150A, 150B, 159, 161, 163, 165, 172, 174, 176, 179, 180

Chinese
1A, 1B, 2A, 5, 10A, 10B, 100A, 100B, 101, 102, 120, 122, 130, 132, 134, 136, C140, 155, 156, 157, 161, 163, 165, 169, 183, C184, C185, 186, 188

City and Regional Planning
110, 111, 112A, 112B, 113A, 113B, 114, 115, 116, 117, 118AC

Civil and Environmental Engineering
167

Classics
10A, 10B, 17A, 17B, 28, 29, 34, 35, 36, 100A, 100B, 110, 121, 124, 130, 155A, 155B, 161, 163, 170A, 170B, 170C, 170D, 175A, 175B, 175C, 175D, 175E, 175F, 180

Cognitive Science
C1, C100, C101, C102, C103, C104, C108, C110, C124, 139

College Writing Programs
N2, 110, C115

Comparative Literature
any, except R1A, R1B, H1A, H1B, R2A, R2B, R3A, R3B

Computer Science
C182

Cuneiform
any

Demography
100, 110, C126, 135, 140, 145AC, C164, C175

Development Studies
any

Dutch
1, 2, 107, 110, 125, 140, 150, 160, 161, 162, 163, C164, 165, 166, 170, 175, 177, C178

East Asian Languages and Cultures
C50, 101-108, C120, C122, C124, C126, C128, C130, 180

East European Studies
1A, 1B, 100

Economics
any

Education
C1, 40AC, 50, 75, 100, 103, 113, 114A, 114B, 114C, C116, C122, 124, 130, 140, 141, C145, C147, 169, 170, 180, 181, 183, 184, 185, 186AC, 187, 188, 189, 190

Egyptian
any

Energy and Resources Group
100, 102, 151, 162, 190

Engineering
120, 124, 191, 195

English
any, except 1A, 1B, 50, 142A, 142D

Environmental Design
C1, 71, C169A, C169B

Environmental Economics and Policy
C1, 2, 100, 101, C115, 118, 140AC, 141, 142, 143, C151, 152, 161, 162, C175, C181

Environmental Science, Policy, and Management
10, 11, C12, 50AC, 60, 100, 101E, 102A, 102B, 102C, 102D, C103, 136, 151, 153, 154, 155, C159, C160, 161, 162, 165, 166, 167, 182, 183, 184, 185, 186, 188, C191

Environmental Sciences
10

Ethnic Studies
20AC, 21AC, 41AC, 100, 110, 122AC, 125AC, 128, 130AC, 133AC, 135AC, 136, 141, 142, 147, 150AC, 159AC, C173, 190

Eurasian Studies
1A, 1B, 2A, 2B, 101A, 101B, 102A, 102B

Film
any

French
1-4, 13, 14, 35, 41-43B, 102, 103A-112B, 114A-119B, 120A-125B, 138-145, 146A-148, 150A-162B, 170-174, 175A-180D, 183A-184B

Gender and Women's Studies
10, 14, C15, 20, R20W, 40, 50AC, 100AC, 101, 102, 103, 104, 111, 120, 125, 131, 139, 140, 141, 142, C146, C153A, C153B

Geography
4-35, 50AC-138, 150AC-159AC, C160A, C160B, 162, 165-169, 180, 181

German
1, 2, 3, 4, 25, 40, 100, 101, 105, C106, C109-123, 130, 132-143, 151-162, 164, 165, 168-171, 175C, C179, 180-185

Greek
1, 2, 10, 40, 100, 101, 102, 105, 115, 116, 117, 120, 121, 122, 123

Health and Medical Sciences
C133

Hebrew
1A, 1B, 20A, 20B, 100A, 100B, 104A, 104B, 105A, 105B

Hindi-Urdu
1A, 1B, 100A, 100B, 101A, 101B

History
any

Industrial Engineering
170, 171

Information
101, C103, 138, 142AC, 182AC

Integrative Biology
C156

Interdepartmental Studies
1, 100AC, 114A, 114B, 170

Interdisciplinary Studies
60, 61, 100A, 100B, 100C, C108, C117, 118AC, 137AC, C145, C160

International and Area Studies
45, 102, 115, 120, 143, C145, 150, C175

Iranian
any

Italian Studies
1, 2, 3, 4, 12, 30, 40, 50, 70, 75, 80, 90, 101A, 101B, 103, 104, 110, 111, 113, 114, 115, 117, 120, 130A, 130B, 140, 150, 155, 160, 170, 175

Japanese
1A, 1B, 10A, 10B, 80, 100A, 100B, 101, 102, 103, C115, 120, 130, 132, 134, 140, 142, 144, 146, 155, 159, 162, 164, C174, C176, 183, 184, 185, 186

Jewish Studies
101

Journalism
141, C183

Khmer
1A, 1B, 100A, 100B, 101A, 101B

Korean
1A, 1B, 10A, 10B, 100A, 100B, 101, 102, 150, 155, 160

Landscape Architecture and Environmental Planning
101, 102, 103, 110, 111, 121, 130, 131AC, 140, 141AC, 170

Latin
1, 2, 10, 40, 100, 101, 102, 115, 116, 117, 118, 119, 120, 121, 122, 123, 140, 155A, 155B

Latin American Studies
10, 150

Legal Studies
any

Letters and Science
16, 17, 18, 21, 22, 40AC, 80A-80S, 116, 118, 120, 122, C160, C180

Linguistics
any, except 18, 41, 44, 47, 48

Malay/Indonesian
any

Mass Communications
any

Mathematics
C103, 160

Medieval Studies
150

Middle Eastern Studies
10, 20, 130, 150

Military Affairs
1, 2, 3, 20, 120, 121, 123, 124, 144, 145A, 154

Molecular and Cell Biology
41, C41X, 61

Music
26AC, 27, 75-77, 128, 128A-128S, 129, 130A, 130B, 131A, 134A, 134B, C134C, 135A, 139, 171B-171E, 172A, 172B, 173B-173F, 174A, 174C

Native American Studies
71, 72, 90, 100, 101, 102, 104, 110, 149, 150, 151, C152, 153, 154, 155, 156, 157, 158, 173, 175, 176, 177, 182, 190

Naval Science
2, 3

Near Eastern Studies
10-C92, 102A-107, 109, 110, 120A-174

Nutritional Science and Toxicology
104, 135, C159

Peace and Conflict Studies
10, 100, 125AC, 127A, 128AC, 135, 149, 150, 151, 153, 154, 155

Persian
1A, 1B, 100A, 100B, 101A, 101B, 102A, 102B, 103A, 103B, 104A, 104B

Philosophy
any, except 12A, 12B

Physical Education
160

Plant and Microbial Biology
10, C41X

Political Economy of Industrial Societies
any

Political Science
any, including 179

Portuguese
8, 11, 12, 25, 26, 101A, 101B, 102, 103, 104, 107A, 107B, 112, 113, 114, 125, 128, C134, 135, 136, 138, 144

Psychology
1, 2, 14, 101-110, C120, C124, 125AC, C129-142, 146-168, 180, 182, C191

Public Health
14, 103, 105, 114, 115, 126, 130AC, 150A, 150B, 150C, 150E, C155, 180, 181

Public Policy
1, 6, 101, 103, 117AC, 156, 159-170, 173-188

Punjabi
1A, 1B, 100A, 100B

Religious Studies
90A, 90B, C90B, C103, C104, C108, C109, C111, 115, 120A, 120B, 123, C124, 125, 130, C132, C133, C135, C156, C157, C161, C162, 163, C164, C165, C166, 171AC, 172AC, C175, C182, C185A, C185B, 190

Rhetoric
20, 22, 40AC, 41AC, 101-110, 119-122, 124-139AC, 141AC, 150, 152AC-157B, 159A, 159B, 162AC, 163AC, 165-173, 176, 177, 178, 180AC, 181

Sanskrit
100A, 100B, 101A, 101B

Scandinavian
1A, 1B, 2A, 2B, 3A, 3B, 4A, 4B, 50, 75, 100A, 100B, 102, C107, C108, 115, 116, 117, C118, 120, 123, 125, 127, 128, 140A, 140B, 150, 155, C160, 165, 170

Semitics
any

Slavic Languages and Literatures
1-4, 6A, 6B, 14, 25A-28B, 36-R37W, 45, 46, 101, 103A-104B, 114-133, 134A-134N, 135, 137-151, 154, 160, 161, 170, 171, 179-190

Social Welfare
any, except 154

Sociology
any

South and Southeast Asian Studies
C51, C52, C145, C186

South Asian
1A, 1B, 108, C114, 121, C123, C127, C128, 129, 130, 138, 139, C140, 141, C142, 143, 145, 155

Southeast Asian
10A, 10B, 122, 123, 124, 128, 129, 130, C164

Spanish
1- 4, 6, 8, 21, 22, 25-39D, 40, 100-102B, 104A-123B, 126-162, 164, 165AC, C178, 179, C179, 185

Tagalog
any

Tamil
1A, 1B, 101A, 101B

Thai
1A, 1B, 100A, 100B, 101A, 101B

Theater, Dance, and Performance Studies
any, except 1A, 1B, 10, 11, 12, 40A, 40B, 60, 66*, 110A, 110B, 111, 141A, 141B, 142A, 142B, 143A, 143B, 144, 146A, 146B, 147, 160, 162, 166*, 170, 172, 173A-176, 177, 181

Tibetan
C114, 120A, 120B, 124, 128A, 128B, 150A, 150B, 167

Turkish
1A, 1B, 100A, 100B, 101A, 101B, 102A, 102B

Undergraduate and Interdisciplinary Studies
C12, 20AC, R44A, R44B, R44C, R55A, R55B, 56AC, C92, 110, 112, 114, 121, C132, C133, C135, C136, C137, C152, C154, C155, 161, 162, 165, 166, 170

Vietnamese
1A, 1B, 100A, 100B, 101A, 101B

Visual Studies
180A, 180B, C185A, 185X

Notes

Unacceptable Courses
Courses that only teach a skill, such as drawing or playing an instrument, are not accepted toward the Breadth requirement.

*Courses marked with an asterisk must be evaluated on an individual basis.

Foreign Language
Elementary courses in a foreign language are acceptable with certain limitations:

- Elementary-level courses may not be in the student's native language and may not be structured primarily to teach the reading of scientific literature.
- For the chemical engineering major, no more than six units of foreign language may be counted toward the 19-unit Breadth requirement.
- For the chemistry or chemical biology major, elementary-level courses in a foreign language are not accepted toward the 15-unit Breadth requirement if they are accepted (or are duplicates of high school courses that are accepted) in satisfaction of the Foreign Language requirement.

Additional Courses
Any course that satisfies the American Cultures requirement or the American History and Institutions requirements will be accepted toward satisfaction of the Breadth requirement. Students can petition for acceptance of a freshman seminar course.

If students would like to take courses that do not appear on this list and the students feel that the courses should count toward the Breadth requirement, they should check with their staff advisers.

ADVANCED PLACEMENT TESTS — CREDIT INFORMATION

Name of Test (*Credit granted by UC)	Score	UC Berkeley Course(s) or Requirement(s) Satisfied
Chemistry (5.3 units)	3 or higher	none
****Math: Calculus AB Calculus AB SUB** (2.7 units)	3 or higher	Math 1A
****Math: Calculus BC** (5.3 units)	3 or 4 5	Math 1A Math 1A and 1B
****Physics B** (5.3 units)	3 or higher	none
****Physics C: Mechanics Electricity & Magnetism** (2.7 units each)	Sum of two tests: 8 or less 9 or higher	 none Physics 7A (Consider taking the Physics honors sequence.)
****English Literature & Composition** (5.3 units)	3 4 5	Entry-Level Writing ***Entry-Level Writing **and** a first-level Reading and Composition course (e.g., English R1A) with 4 units of credit toward the Breadth requirement (Group I) ***Entry-Level Writing **and** first- and second-level Reading and Composition courses (e.g., English R1A and Rhetoric R1B) with 5.3 units of credit total toward the Breadth requirement (Group I)
****English Language & Composition** (5.3 units)	3 4 or 5	Entry-Level Writing ***Entry-Level Writing **and** a first-level Reading and Composition course (e.g., English R1A) with 4 units of credit toward the Breadth requirement (Group I)
Art: History of Art History: European United States World Music Theory (5.3 units each)	3 or higher	3 units of credit (for each test) toward the Breadth requirement (Group II)
Economics: Microeconomics Macroeconomics Government & Politics: Comparative United States Human Geography Psychology (2.7 units each)	3 or higher	2.7 units of credit (for each test) toward the Breadth requirement (Group II)

Name of Test (*Credit Granted by UC)	Score	UC Berkeley Course(s) or Requirement(s) Satisfied
French Literature **Spanish Literature** (5.3 units each)	3 or higher	For **chemical engineering** majors, 3 units of credit (for each test) toward the Breadth requirement (Group II) ****For **chemistry** or **chemical biology** majors, each test satisfies either the Foreign Language requirement or 3 units of credit toward the Breadth requirement (Group II)
French Language **German Language** **Spanish Language** (5.3 units each)	3 or higher	For **chemical engineering** majors, 5.3 units of credit (for each test) toward the Breadth requirement (Group II) *Note:* For chemical engineering majors, no more than 6 units of foreign language may be counted toward the Breadth requirement (Group II) ****For **chemistry** or **chemical biology** majors, each test satisfies either the Foreign Language requirement or 5.3 units of credit toward the Breadth requirement (Group II)
Latin: **Literature** **Vergil** (2.7 units each)	3 or higher	For **chemical engineering** majors, 2.7 units of credit (for each test) toward the Breadth requirement (Group II) ****For **chemistry** or **chemical biology** majors, each test satisfies either the Foreign Language requirement or 2.7 units of credit toward the Breadth requirement (Group II)
****Art: Studio Art** (5.3 units each)	3 or higher	Does not satisfy any college/major requirement
Biology (5.3 units)	3 4 or 5	Does not satisfy any college/major requirement For **chemical biology** or **chemical engineering** majors, 1A and 1AL For **chemistry** majors, does not satisfy any college/major requirement *Note:* With a score of 4 or 5, students receive subject credit for Biology 1A, 1AL, and 1B as prerequisite to other courses. Consult the Career Center regarding the use of tests for admission to professional schools.
****Computer Science A** (1.3 units) ****Computer Science AB** (2.7 units)	3 or higher	Does not satisfy any college/major requirement
Environmental Science **Statistics** (2.7 units each)	3 or higher	Does not satisfy any college/major requirement

* The University of California grants unit credit for all Advanced Placement tests on which a student scores 3 or higher. The unit credit is posted on the student's UC Berkeley transcript and is included in the UC Berkeley unit total.

** Students who have passed both the English Literature and Composition and the English Language and Composition tests will receive a maximum of only 5.3 units of credit (total) for these tests. This is also true for the Math Calculus AB and Math Calculus BC tests, for the Physics B and Physics C tests, and for the Art Studio tests. Students who have passed both the Computer Science A and the Computer Science AB tests will receive a maximum of only 2.7 units of credit (total) for these tests.

*** **Reading and Composition Requirements:**
For the **chemistry** or **chemical biology** major, both first- and second-level Reading and Composition courses are required.
For the **chemical engineering** major, only a first-level Reading and Composition course is required.

**** For the **chemistry** or **chemical biology** major, credit for an elementary foreign language cannot be applied to the Breadth requirement if the same foreign language is used to satisfy the Foreign Language requirement.

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