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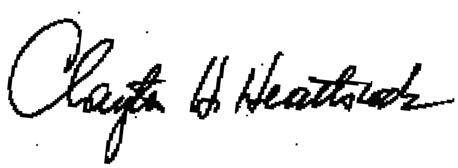
To Prospective Students

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, 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. Five centers of excellence—in organic synthesis, marine bioproducts, 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. 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
Dean, College of Chemistry

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 72 faculty members are one Nobel laureate, two Fellows of the Royal Society of London, 18 members of the National Academy of Sciences, and 6 members of the National Academy of Engineering. 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, 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 opportunity 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.

Student Activities and Services

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.

The following national organizations also have Berkeley student chapters: The National Society of Professional Engineers; Society of Women Engineers; Society of Petroleum Engineers; and Toastmasters.

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) and 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.

Many students participate in the Engineers Peer Advising Center (EPAC), an academic counseling service offered by engineering students and located in the Stephen D. Bechtel Engineering Center.

The Chemistry and Chemical Engineering Alumni Association provides online mentoring to interested students.

Additional infomation on these and other student services, such as the Disabled Students' Program, is available in other campus publications and web sites. The UC Berkeley home page is at www.berkeley.edu; the College's home page is at http://chemistry.berkeley.edu.

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. The Housing and Dining Services Office, University of California, Berkeley, 2610 Channing Way #2272, Berkeley, CA 94720-2272 will send descriptive material on request. You can also visit the housing web site at www.housing.berkeley.edu.

Cooperative Education Programs

Engineering Cooperative Education Program

The Engineering Cooperative Education Program provides students majoring in engineering (including chemical engineering) with the opportunity to work in industrial organizations and government agencies while they are in the process of completing their engineering education. Co-op students take leaves of absence from the University for the six- to eight-month work experience (during one semester and possibly a summer) and then return to continue their studies. Up to three work periods are permitted, though such a choice would delay graduation by three semesters or more.

A number of West Coast firms and governmental agencies cooperate in the co-op program. They offer work experience in various fields, including chemical manufacturing, chemical instrumentation, chemical engineering processes, electronics, and nuclear technology.

During work periods, the student is a regular employee of the cooperating employer. All jobs are actual positions, selected to fit student needs. Cooperative students receive the normal compensation for the jobs they hold. Each job entails responsibility appropriate to the student's level of education and work experience. The complexity and challenge of jobs increase with successive work periods.

To be eligible for the program, a student must have completed the freshman year, be at least of sophomore standing, and have an overall grade-point average of 2.3. Students transferring to Berkeley must put in one semester of course work at Berkeley before they begin cooperative education program jobs.

The subject requirements of the curricula apply equally to all students, although for cooperative students the scheduling of courses may differ. Cooperative students may be granted permission to take extension courses for degree credit while engaged in work assignments.

Comprehensive information can be obtained from the office of the Engineering Cooperative Education Program, University of California, Berkeley, 306 McLaughlin Hall #1702, Berkeley, CA 94720-1702, (510) 642-6385. The web address is www.coe.berkeley.edu/coop.

Cal Connections

Cal Connections (formerly the Cooperative Education/Internship Program) lists cooperative education opportunities for chemistry majors online at http://career.Berkeley.EDU/Fulltime/fulltime.stm. Cal Connections also offers general internship counseling and several other services to assist students in their career exploration. Interested students may obtain further details from the Career Center, University of California, Berkeley, 2111 Bancroft Way #4350, Berkeley, CA 94720-4350, (510) 642-1532. The e-mail address is coopl@uclink.berkeley.edu, and the web address is http://career.berkeley.edu.

Berkeley Programs for Study Abroad

While progressing toward your undergraduate degree in the College of Chemistry, you have an opportunity to earn credit toward the degree 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. The e-mail address is eapucb@uclink.berkeley.edu and the web address is www.uoeap.ucsb.edu.

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 make application through the Office of Financial Aid will automatically be considered for these scholarships.

Contact the Office of Financial Aid, University of California, Berkeley, 211 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 the Web site at uga.berkeley.edu/fao/.

The California Alumni Association offers merit-based leadership scholarships. You may contact the California Alumni Association Scholarship Office at (510) 642-7281 for more information, or go to www.alumni.berkeley.edu/students/Scholarships_and_Awards/main.asp.

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 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. Undergraduates majoring in chemical engineering or chemistry receive special access cards which remain valid until graduation.

The Stephen D. Bechtel Engineering Center auditorium accommodates large audiences to hear visiting speakers, and conference rooms provide a place where students can meet with professional engineers and alumni. In addition, the center houses the offices of student organizations with adjoining lounges for informal student activities.

The Chemistry Library, serving both the Chemistry and Chemical Engineering Departments, houses some 50,000 volumes and 650 serial subscriptions. Collections of thermodynamic and spectra data enrich this library's resources. Other branch libraries on the campus, such as Physics, Engineering, Biosciences, Natural Resources, and Public Health, supplement the Chemistry Library's collections; links with these and other libraries provide access to a vast amount of information.

The Chemistry Library makes available to students a large number of electronic resources via the library web site, www.lib.berkeley.edu/CHEM.

Alumni, Development, and Public Affairs

All graduates are invited to join the college's Chemistry and Chemical Engineering Alumni Association. No dues are charged. Students also can become involved with Alumni Association activities while they are still enrolled. For example, the Alumni Association sponsors a mentorship program for undergraduates.

All alumni receive the *News Journal of the College of Chemistry,* a semiannual publication written specifically for them. Current news stories are posted on the Web at www.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, and facilities.

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. 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 the 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.

In addition to the excellent research facilities in the college complex, 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, the Materials and Molecular Research Division, and the Melvin Calvin Laboratory, which is a Division of LBNL.

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 systems; electronics; computing and networking; 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, and visible and ultraviolet spectrophotometers, 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

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 options 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 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 double major programs** (Chemical Engineering and Materials Science and Engineering, and Chemical Engineering and Nuclear Engineering) are offered through the College of Chemistry.

Note: Biochemistry is not offered in the College of Chemistry. Biochemistry and Molecular Biology is offered as an option in the Molecular and Cell Biology B.A. program in the College of Letters and Science.

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 visit the web site at www.berkeley.edu/catalog/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. You can 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 double 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 change to a double 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 or chemical engineering should include in their high school program: chemistry (one year); 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 the many community colleges throughout California. Up to 70 UC-transferable semester units may be transferred from a community college.

In addition to satisfying UC minimum eligibility requirements, College of Chemistry transfer applicants are expected to complete, at a minimum, a year of general chemistry lecture and laboratory and courses equivalent to Mathematics 1A-1B, Physics 7A (calculus-based mechanics and wave motion), and English R1A (plus English R1B for chemistry majors) by the end of the spring term before transfer. Chemical engineering majors are also expected to complete a course in computer programming for science or engineering students (using a computer language such as FORTRAN, C, C++, Pascal, ADA, Machine language, or Matlab) before transfer. In addition, completion of additional chemistry, mathematics, and calculus-based physics is encouraged. Chemistry majors who transfer without having covered quantitative analysis are required to take Chemistry 5 after transfer. Please note that course work taken the summer before enrollment at Berkeley is not considered in the selection of applicants.

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 English Composition and Literature Requirement for Chemical Engineering (English 1A) and Chemistry (English 1A-1B). However, IGETC does not satisfy the entire breadth requirement.

Academic Requirements

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;
• achieve a grade of C- or higher in Chemistry 4B before taking more advanced courses;
• achieve a grade of C- or higher in Chemistry 112A before taking Chemistry 112B; and
• achieve 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 students must also:

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

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

Chemical engineering students who do not achieve a grade of C- or higher in Chemical Engineering 140 on the 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.

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 schedules.

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 for fewer than 13 or more than 19 1/2 units per semester. In addition, ordinarily students will not be permitted to enroll for 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 requirement as soon as possible so they have a foundation for courses that require writing skills. Note that English 1A or equivalent is prerequisite for Chemical Engineering 185.

Changes to Planned Class Schedules

Students are required to consult with their college advisers concerning proposed changes to their planned class schedules. Failure to obtain college adviser approval for changes can result in disciplinary action. After the third week of classes, proposed changes to class schedules (course adds/drops and grading option changes) must be submitted to college advisers on petitions to change class schedule.

The deadline for adding courses without a fee is the Friday of the third week of classes, and the deadline for adding courses with a fee is the Friday of the fifth week of classes. The deadline for dropping courses without a fee is the Friday of the second week of classes, and the deadline for dropping courses with a fee is the Friday of the eighth week of classes. The deadline for changing grading option (*passed/not passed* to a letter grade or vice versa) is the Friday of the eighth week of classes.

After the above deadlines the associate dean's approval is required for class schedule changes (course adds/drops and grading option changes). All courses for which a drop is *processed after the eighth week of classes* will appear on the student's official transcript permanently, with a notation showing the week number in which the course was dropped. Under no circumstances will the college waive the transcript notation.

Limit on Semesters

Students in the College of Chemistry who entered UC Berkeley as freshmen are allowed eight semesters to graduate. Chemistry majors who entered UC Berkeley as transfer students are allowed four semesters to graduate. Chemical Engineering majors who entered UC 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.

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 that having a double major or simultaneous degrees will not necessarily improve your chances for admission to graduate programs or to the career of your choice.

Withdrawal and Readmission

Students who find it necessary to discontinue attending classes during a semester must formally request a withdrawal from the University by contacting their college 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 *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 college 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 UC 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.

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 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 college adviser or the dean.

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 college adviser.

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.

Senior Residence Requirement

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. Dean's approval for the modified senior residence requirement must be obtained before enrollment in the Education Abroad Program.

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 majors, 15-unit breadth requirement except for English composition; foreign language requirement;

• 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.

Honors Research

Junior or senior students who have at least a 3.4 overall grade-point average at Berkeley can take Chemistry or Chemical Engineering H194, Research for Advanced Undergraduates. Students contemplating graduate study in chemistry or chemical engineering are particularly urged to include H194 in their course program. 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

Course credit for Chemical Engineering or Chemistry H194 is not required for receipt of honors at graduation. Honors at graduation are awarded in accordance with general campus regulations listed in the *General Catalog.*

Additional Information

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 and 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

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

Admission

Both departments have detailed brochures that describe their graduate programs. A brochure and the appropriate application forms and deadlines for both admission and financial support may be requested from the department of interest. 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 year-round. 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. No other appointment in the University, including teaching in University Extension, may be accepted.

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 require only 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 our nation's 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 ten years after having begun their industrial career. 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, mathematics, and English. Later: fluid flow, heat transfer, mass transfer, separations, engineering thermodynamics, materials engineering, chemical reaction engineering, process design, and technical communication. In advanced and graduate programs: application areas such as electrochemical engineering, polymers and soft materials, microelectronics processing and MEMS, catalysis, biochemical 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. Seventeen 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 from neighboring research and industrial establishments 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 130, are equipped for studies of surface catalysis, phase equilibria, polymer chemistry and physics, water pollution control, biochemical processes, computer control of processes, flow through porous media, food processing, coal liquefaction, plasma processing, fluid-particle systems, ion exchange, and others.

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 Berkeley campus American Cultures requirement affirms the value difference plays in generating knowledge.

The technical curriculum in chemical engineering seeks to provide students with a broad education emphasizing an excellent foundation in scientific and engineering fundamentals. This curriculum is designed with the assumption that secondary school and/or community college prerequisites for admission result in student familiarity with basic sciences and mathematics.

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.

• 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 processes and of process equipment. It prepares one for employment in such industries as organic chemical, petroleum, inorganic chemical, 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 scientific and engineering fields.

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

• have satisfactorily completed a *minimum of 128 units;*

• have satisfactorily completed a minimum of 48 engineering units excluding both Engineering 77 and Chemical Engineering 185; and also

• have satisfied the following requirements for lower division, upper division, and additional electives and options.

In addition, the student must fulfill the scholarship requirements specified in the "Academic Requirements" section of this announcement (see Table of Contents).

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

Lower Division

The suggested course program for the first two years may be taken at Berkeley, at one of the community colleges in the state, or at another accredited institution. It is particularly important for students who plan to transfer to the college as juniors to take adequate mathematics and physics in their first two years. Insufficient mathematics and physics will prevent students from taking physical chemistry in the junior year.

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

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 that a grade of C- or better is required in Chemistry 4A before taking 4B and also in Chemistry 4B before taking more advanced courses. Students who plan to take Chemistry 112B must receive a grade of C- or better in 112A before taking 112B.

[2]**Chemical Engineering.** 140, 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.

[3]**Molecular and Cell Biology.** 102.

Engineering. 45, 77. Engineering 77 must be taken before Chemical Engineering 140. Engineering 45 is generally taken in the fall of the junior year. (Note: Computer Science 9A or 61A can be substituted for Engineering 77.)

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

Physics. 7A, 7B, 7C. This program should start in the second semester of the freshman year. (Note: Physics 7C can be replaced with one of the following Chemistry electives: 104A, 104B, 105, 108, 112B, 113, 115, 120B, 122, 125, 130A, 143, or 146. Students who plan to take Physics 137A in lieu of Chemistry 120A must take Physics 7C.)

Subject A. The University assumes that you are proficient in English and in writing about academic topics. Fulfillment of the Subject A requirement is a prerequisite to enrollment in all freshman reading and composition courses. If you have not passed the Subject A examination or otherwise fulfilled the requirement when you enter the University, you should enroll in College Writing 1A during your first or second semester. College Writing 1A is a 6-unit course that satisfies the Subject A requirement and a first-level English composition course (e.g., English 1A). Detailed information about this general University requirement is available in the *General Catalog.*

English Composition and Literature. The student must demonstrate reasonable proficiency in English composition by satisfactory completion of one of the courses listed in this announcement under "Breadth Requirement; Group I, English Composition and Literature." This course may *not* be taken on a P/NP basis. It is a prerequisite for Chemical Engineering 185.

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 office for verification of course acceptance. After admission to Berkeley, credit for English at another institution will not be granted if the Subject A requirement has not yet been satisfied.

[1]**19-Unit Breadth Requirement.** The student must include one course in English composition (see English Composition and Literature above) and additional courses in humanities, social sciences, or composition. Refer to the breadth requirement 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.

[1]**American Cultures.** The American cultures breadth requirement is satisfied by passing, with a grade not lower than C- or P, an American cultures course. See the Schedule of Classes for the specific American cultures courses offered each semester. Detailed information about this Berkeley campus requirement is available in the *General Catalog* or on the web site at learning.berkeley.edu/AC.

[1]**American History and Institutions.** The American History and Institutions requirements are normally satisfied by high school work with sufficiently high grades in these subjects. Detailed information about these general University requirements is available in the *General Catalog* or on the web site at learning.berkeley.edu/ahi.

The following program is suggested for the first two years. Note that 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 or 7C, Engineering 45, 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	-
Engineering 77	-	4
Mathematics 1A-1B	4	4
Physics 7A	-	4
English Composition	4	-
Breadth Elective[1]	4	-
Total	**17**	**16**
Sophomore Year		
Chemistry 112A	5	-
Chemical Engineering 140, 150A[2]	4	4
Mathematics 53, 54	4	4
Physics 7B-7C (or Physics 7B and a Chemistry elective)	4	2-5
Molecular and Cell Biology 102[3]	-	4
Total	**17**	**14-17**

Upper Division

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

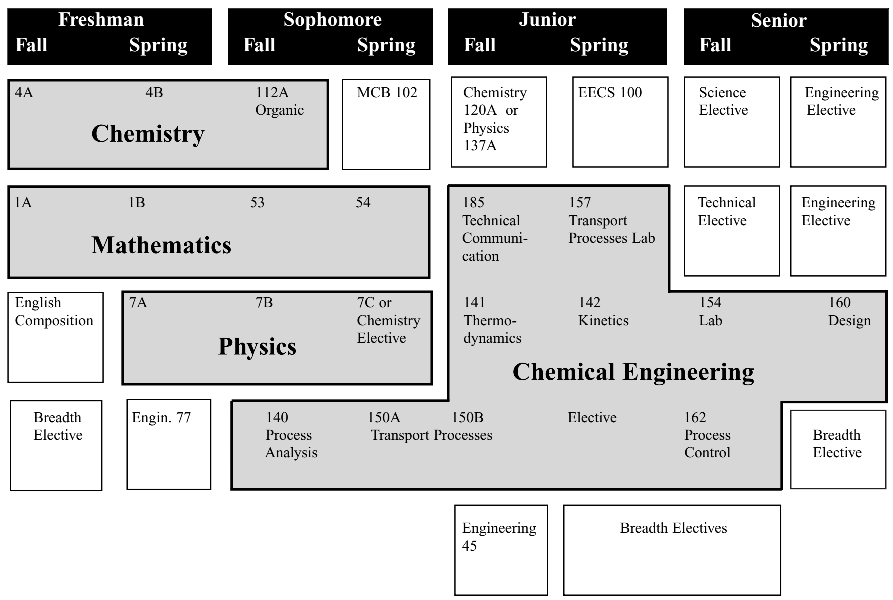
Chemistry. 120A, or Physics 137A.

Chemical Engineering. 141, 142, 150B, 154, 157, 160, 162, 185.

Note: While enrolled in 140, the introductory chemical engineering course, students are required to take a screening exam to determine their eligibility for Chemical Engineering 185. Students who fail that exam are required to complete another writing course before enrolling in Chemical Engineering 185.

Students who pass the screening exam are eligible to take another exam that will exempt them from the 185 requirement.

Representative Undergraduate Chemical Engineering Program



Electrical Engineering and Computer Sciences. 100.

3 Units of Advanced Technical Elective. Students must complete 3 units of advanced technical elective selected from the "Suggested Technical Electives" section of this announcement (see Table of Contents).

Additional Electives and Options

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 *focused option program* with the option 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 focused option program cannot also be used toward satisfaction of another college or major requirement. A maximum of 6 units of research can be applied toward electives, including the advanced technical elective.

Open Elective Program

Students who do not choose a focused option program 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.)
- 6 units of engineering electives chosen **from the engineering and chemical engineering courses** listed in the "Suggested Technical Electives" section of this announcement (see Table of Contents) or approved by the student's faculty adviser.

Focused Option Programs

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

Note: Students who choose to replace Physics 7C with Chemistry 112B may not use Chemistry 112B toward a focused option program.

Biotechnology
- Chemistry 112B or Molecular and Cell Biology C112
- Chemical Engineering 170 and 170L
- 3 units chosen from the following: Bioengineering 115, 118, 121, C153, C176, Civil Engineering 114

[4]Chemical Processing
- Chemistry 104A or 112B
- 6 units of chemical engineering electives chosen from the following: C133, 170, 170E, 170L, 170M, 171, 175, 176, 178, 179, 181, 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, 113, 118, 120, 121, 122, 123, 160, Mechanical Engineering 140, 151

Environmental Technology
- Chemistry 112B or 104A
- Chemical Engineering 170
- 6 units chosen from the following: Chemical Engineering 176, Civil Engineering 108, 109, 110, 111, 113, 116, 118, 173, Engineering 150, 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, 178, 179, 181
- 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, 123, 124, 125, Mechanical Engineering 122, 127

Applied Physical Science
- The advanced technical elective required above in the “Upper Division” section must be an engineering course.
- 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 engineering and chemical engineering courses listed in the “Suggested Technical Electives” section of this announcement (see Table of Contents)

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

[2]Transfer students entering in the junior year without Chemical Engineering 140 and 150A will take these courses in the junior year.

[3]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 courses.

[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.

Double Major Programs

Double 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 double major program after they attain sophomore standing.

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, new reactor types.

*Double Major Program in Chemical Engineering and Materials Science and Engineering — 130-131 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
Engin 77, Introduction to Computer Programming for Scientists and Engineers	-	4
[1]English 1A or Equivalent	4	-
[1]Breadth Elective	4	-
Total	**16**	**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
Chemistry 112A, Organic Chemistry	5	-
Chem Eng 140, Introduction to Chemical Process Analysis	4	-
Chem Eng 150A, Transport Processes	-	4
Engin 45, Properties of Materials	-	3
Total	**17**	**15**
Junior Year		
[2]EECS 100, Electronic Techniques for Engineering or EECS 40, Introduction to Electrical Engineering	4	-
Mat Sci 120, Materials Production	3	-
Mat Sci 102, Bonding and Crystallography	3	-
Mat Sci 103, Phase Transformations and Kinetics	-	3
[3]Mat Sci restricted course	-	3-4
Chem Eng 141, Chemical Engineering Thermodynamics	3	-
Chem Eng 142, Chemical Kinetics and Reaction Eng	-	3
Chem Eng 150B, Transport and Separation Processes	4	-
[4]Chem Eng 185, Technical Communication	-	3
[1]Breadth Elective	-	4
Total	**17**	**16-17**
Senior Year		
[3]Mat Sci restricted courses	6	3
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	-	4
Chem Eng 162, Dynamics and Control of Chemical Processes	-	4
[1]Breadth Electives	4	3
Total	**16**	**17**

*Students must complete a minimum of 23 upper divison 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.

[2]For Chem. Engin./Mat. Sci. students, Elec. Engin. 40 may be taken but it would leave a shortage of one or two upper division College of Engineering units.

[3]Restricted Options for Chem. Engin./Mat. Sci. must include four courses from Mat. Sci. 104, 111, 112, 113, 117, C118, 121, 122, 123, and 125. Either one or two of these courses should be chosen from Mat. Sci. 121, 122, 123, and 125.

*Double Major Program in Chemical Engineering and Nuclear Engineering — 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
Engin 77, Introduction to Computer Programming for Scientists and Engineers	-	4
[1]English 1A or Equivalent	4	-
[1]Breadth Elective	4	-
Total	**16**	**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 150A, Transport Processes	-	4
Engin 45, Properties of Materials	3	-
EECS 100, Electronic Techniques for Engineering	-	4
Total	**15**	**16**
Junior Year		
Engin 117, Methods of Engineering Analysis	3	-
Nuc Eng 101, Nuclear Reactions and Radiation	4	-
Nuc Eng 150, Nuclear Reactor Theory	-	3
Chem Eng 141, Chemical Engineering Thermodynamics	3	-
Chem Eng 142, Chemical Kinetics and Reaction Engineering	-	3
Chem Engin 150B, Transport and Separation Processes	4	-
[4]Chem Eng 185, Technical Communication	3	-
[1]Breadth Electives	-	8
Total	**17**	**14**
Senior Year		
[5]Nuc Eng 104A, Radiation Detection and Nuclear Instrumentation Lab	3	-
Nuc Eng 120, Nuclear Materials	3	-
Nuc Eng 124, Radioactive Waste Management	3	-
Nuc Eng 161, Nuclear Power Engineering	-	3
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	-	4
Chem Eng 162, Dynamics and Control of Chemical Processes	-	4
[1]Breadth Elective	-	3
Total	**15**	**17**

[4]For students who demonstrate by examination satisfactory ability in technical writing, the requirement of Chem. Engin. 185 will be waived.

[5]Nuclear Engineering 104B may be substituted.

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, 170, 170E, 171, 173, 176, 178, 179, and 181. 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, students must submit a notification of completion of the minor at 420 Latimer Hall.

Note: Consult with your college/school for information on rules regarding overlap of courses between the student's major and minor.

Suggested Physical and Biological Science Courses

The following departments offer courses that satisfy the science elective for the open elective program. Students should select a course in consultation with their faculty adviser.

Anthropology 1, 108, 109, 131, 132, 133, 134, 135

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

Biology 1A, 1B

Chemistry 104A, 104B, 105, 108, 112B, 113, 115, 120A, 120B, 122, 125, 130A, 130B, 143, 146, 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, 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, 164, 172, 180, 181, 185, 186

Environmental Sciences 10, 125

Geography 1, 40, C136, 140A, C141, 143, 144, C145, 147, 148, 149, 171, 185

Integrative Biology 15, 31, 32, 33, 34, 41, 60, 82, 100A, 100B, C101, C101L, 102, 102L, 103, 103L, 104, 104L, 106, 106A, C107, C107L, 108, 117, 117L, 123A, 124, 130, 131, 135, 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

Letters and Science 16, 18, 19, 117

Molecular and Cell Biology 14, 32, 41, C41X, 50, 61, 64, C103, 111, C112, 113, C114, 115, C116, 130, 131, 133, 135A, 135E, 135G, 135K, C135V, 136, 140, 142, 150, 152, 160, 163, 166

Nutritional Sciences and Toxicology 10, 106, 107, 110, 113, 150, 160

Physics 21, 105, 110A, 110B, 112, 124, 129A, 132, 137A, 137B, 138, 141A, 177

Plant and Microbial Biology 10, 40, C41X, C102, C102L, C103, C107, C107L, 110, 110L, C112, C114, 120, 120L, 135, 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, 170B, 171C, 172

Suggested Technical Electives

Note: A course used toward satisfaction of the advanced technical elective requirement cannot also be used toward satisfaction of another college or major requirement.

Open Elective Program

The advanced technical elective and the two engineering elective courses must be selected from the list below, or from among the courses listed under the focused option programs (see page 14). A minimum of 6 units must come from College of Engineering or Department of Chemical Engineering courses.

Focused Option Program

The advanced technical elective must be selected from the list below, or from among the courses listed under the focused option programs (see page 14).

Courses in the College of Engineering

Bioengineering 100

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

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

Engineering 102, 117, 118, 120

Industrial Engineering and Operations Research 160, 162

Materials Science and Engineering 112, 113, 120, 121, 122, 123, 124

Mechanical Engineering 127, 140, 142, 151, 161, 185

Nuclear Engineering 101, 124

Courses in Other Departments

Business Administration (UGBA) 110, 140

Chemical Engineering C133, 170, 170E, C170L, 170M, 171, 175, 176, 178, 179, 181, H194, 196

Chemistry 104A, 104B, 105, 108, 112B, 113, 115, 120A, 120B, 122, 125, 130A, 130B, 143, 146, 192, H194, 196

Earth and Planetary Science 105, 106, 111, 131

Economics 121

Environmental Science, Policy, and Management 124

Geography 130, 144, 146

Integrative Biology 131

Mathematics 121A, 121B, 128A, 128B

Molecular and Cell Biology C112, 130, 136

Nutritional Sciences and Toxicology 106, 110

Physics 110A, 110B, 112, 137A

Statistics 25, 134, 135, 150

Note: Statistics 21 is not an acceptable technical elective.

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 9 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.

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. Twelve units derive from a required core of four chemical engineering courses in the areas of mathematics, thermodynamics, reaction engineering, and transport phenomena. An additional 9-unit sequence in an outside specialty is required, and 9 additional units must be taken from departmental graduate electives. 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 interest.

To develop the creative talents of the student, a paramount emphasis in the Ph.D. program is placed on intensive research, a project on which students work closely with one or more 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 students' research directors are used by a committee of the faculty to evaluate the students' 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 students' research programs, 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 a 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.

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.

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

Electronic materials are used in numerous applications, including electronic, optical, and magnetic devices for information processing 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. *(F)*

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 or Chemical Engineering major or consent of instructor. Chemistry 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)*

Upper Division Courses

C133. Microfabrication Equipment Laboratory. (2) One hour of lecture and three hours of laboratory per week. *Prerequisites: Physics 7B, Math 53 and 54, Electrical Engineering 40 or 100; an upper division course on microfabrication technology or manufacturing is recommended but not required (e.g., 179, Electrical Engineering 143, Mechanical Engineering 101, 122, Materials Science 111, 123, 125).* Experiments and simulations illustrating the fundamental principles of equipment and measurement technology for microelectronic and microelectromechanical fabrication and manufacturing. The experiments involve investigation and measurements of high vacuum systems, plasma-assisted etching and film deposition, high temperature silicon oxidation, photolithography, spin coating, chemical-mechanical polishing, and electroplating. Also listed as Electrical Engineering C133, Materials Science and Engineering C133, and Mechanical Engineering C123.

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; Engineering 77N, Computer Science 9A or 61A, or an acceptable computer programming transfer course for science or engineering students; and 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. *Prerequisite: 140 with a grade of C- or higher.* Thermodynamic behavior of pure substances and mixtures. Properties of solutions, phase equilibria. Thermodynamic cycles. Chemical equilibria for homogeneous and heterogeneous systems. *(F)*

142. Chemical Kinetics and Reaction Engineering. (3) Three hours of lecture and one hour of discussion per week. *Prerequisite: 141.* 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. *Prerequisite: 150A with a grade of C- or higher.* 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, 185 or demonstration of competence by exam.* 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. *Prerequisite: 150A and 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) Two hours of lecture, one hour of discussion, and four hours of laboratory 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 laboratory processes and process simulations. *(F, S)*

170. Biochemical Engineering. (3) Courses 170E and 170M will restrict credit if completed before 170. Three hours of lecture per week. *Prerequisite: 150B.* Design, operation, and analysis of process in the biochemical industries. Fermentation and recovery of biochemical products. *(F)*

170E. Environmental Biotechnology. (3) Courses 170 and 170M will restrict credit if completed prior to 170E. Three hours of lecture per week. *Prerequisites: 150B or Civil Engineering 105 or equivalent or consent of instructor.* This course will focus on the application of biotechnology and chemical engineering to environmental problems. The first part of the course will focus on the application of the basic principles of chemical engineering to the environment. In particular, the class will look at homogeneous and heterogeneous systems. The second part of the course will introduce students to microbial growth, physiology, and genetics and how these can be manipulated to remediate toxic contaminants. In the final part of the course, students will use the microbiology and chemical engineering skills together to solve some very important environmental problems. Case studies from the literature will be used to demonstrate these principles. Heavy emphasis will be placed upon the recent literature. *(S)*

C170L. Biochemical Engineering Laboratory. (3) Six hours of laboratory and one hour of lecture per week. *Prerequisite: 170 or 170E (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)*

170M. Marine Biotechnology. (3) Courses 170 and 170E will restrict credit if completed prior to 170M. Three hours of lecture per week. *Prerequisite: 150B.* Fundamental principles of chemical engineering applied to the design, operation, and analysis of bioprocesses, with an emphasis on the emerging industry of marine biotechnology. Of particular interest are the cultivation of marine microorganisms and the recovery of marine bioproducts. Topics include new strategies for the discovery and develpment of new marine bioproducts, bioreactor design for marine bacteria and photosynthetic microalgae, including scale-up, and downstream processing of complex marine natural products. *(F)*

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)*

175. Selection and Evaluation of Chemical Processes. (3) Three hours of lecture per week. *Prerequisite: 160 (which may be taken concurrently).* Development and discussion of cases involving engineering of chemical processes. Process selection and synthesis. Evaluation of process alternatives.

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. *(S)*

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)*

181. Processing of Advanced Polymeric Materials. (3) Three hours of lecture per week. *Prerequisites: 150A and 150B or equivalents; C178 or equivalent recommended.* Study of polymer rheology and polymer processing operations, including extrusion, calendaring, fiber and film formation, compression and injection molding, and mixing. Process analysis utilizes an understanding of rheology, fluid mechanics, and heat transfer to determine operating characteristics and the development of material structure and properties.

185. Technical Communication for Chemical Engineers. (3) Three hours of lecture per week. *Prerequisites: 140; satisfactory completion of UC Subject A requirement; satisfaction of the ChE 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. (2-3) 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. 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)*

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*. *(F, S)*

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. *(S)*

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. *Prerequisites: 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. *(S)*

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. *(F)*

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. *(S)*

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. *(S)*

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. *(S)*

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)*

251. Mass Transfer and Separations. (3) Three hours of lecture per week. *Prerequisite: 250 or equivalent.* Frames of reference in diffusion, concentrations, and velocities in mixtures, fluxes, and forces. Diffusion coefficients, multicomponent diffusion and heat transfer. Mass transfer at a phase boundary. High rates of mass transfer; mass transfer and chemical reaction. Comparison, evaluation, and selection of methods for enhancing separating mixtures. Approaches for selectivity and capacity, reducing energy consumption, and adapting process configurations to separations needs. *(F)*

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.

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. *(S)*

295C. Applied Molecular Theory for Chemical Engineers. (3) Three hours of lecture and one hour of discussion per week. *Prerequisite: Graduate standing in chemical engineering or consent of instructor.* An introduction to quantum and statistical mechanical theories and computational techniques, with the specific purpose of applying these approaches to problems of interest to chemical engineers. Elements of Hartree-Fock molecular orbital theory, density functional theory, equilibrium ensemble theory, nonequilibrium statistical mechanics, transition state theory, and molecular simulations are developed and then applied to a wide range of problems.

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. *(S)*

295E. New Concepts in Heterogeneous Catalysis and Reaction Engineering. (2) Two hours of lecture per week. *Prerequisite: Open to properly qualified chemical engineering and chemistry graduate students.* This course surveys new concepts and methods in heterogeneous catalysis and chemical reaction engineering through detailed reviews and discussions of selected studies from the recent literature. This course covers new inorganic synthesis and spectroscopic characterization methods applied to heterogeneous catalysts, experimental and theoretical techniques for mechanistic studies of chemical reactions at surfaces, and modern descriptions of diffusive and hydrodynamic processes within porous solids and chemical reactors. *(S)*

295K. Current Topics in Metabolic Engineering. (1) One hour of lecture per week. *Prerequisites: MCB 102 or equivalent, 170 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. *(F)*

295N. Polymer Physics. (3) Three hours of lecture per week. *Prerequisites: 230 and 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 multiphase polymer systems, mechanical properties, response to mechanical and electric fields, and fracture. When possible, we 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. *(S)*

295O. Chemical Engineering Management. (3) One 2-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. *(S)*

C295R. Applied Spectroscopy (3) Three hours of lecture per week. *Prerequisites: Graduate standing in engineering, physics, chemistry, or chemical engineering; courses: quantum mechanics, linear vector space theory.* After a brief review of quantum mechanics and semi-classical 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. *Prerequisite: Consent of instructor.* Special laboratory and theoretical studies. May be repeated for credit. Must be taken on a *satisfactory/unsatisfactory* basis. *(F, S)*

298. Seminar in Chemical Engineering. (1) Variable from 1 to 2-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. Must be taken on a *satisfactory/unsatisfactory* basis. *(F, S)*

299. Research in Chemical Engineering. (1-12) Individual conferences. *Prerequisite: Consent of instructor.* Research. May be repeated for credit. Must be taken on a *satisfactory/unsatisfactory* basis. *(F, S)*

602. Individual Studies for Graduate Students. (1-8) Individual conferences. *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. Must be taken on a *satisfactory/unsatisfactory* basis. *(F, S)*

Professional Courses

300. Profession Preparation: Supervised Teaching of Chemical Engineering. (2) Individual conferences and participation in teaching activities. *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. Must be taken on a *satisfactory/unsatisfactory* basis. *(F, S)*

Department of Chemistry

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; 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 molecules.

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, a student may find a research or technical position in a variety of industries such as oil, chemical, food processing, agriculture, photographic, pharmaceutical, 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 with a higher degree in another field can lead to many unique and rewarding careers. The B.A. in chemistry 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 and the environment 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.

In general, the outlook is bright for anyone wishing to study chemistry seriously.

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, biophysical, and nuclear chemistry. Laboratory experience is provided in inorganic and organic synthesis, analytical methods, physical chemical measurements, spectroscopy, 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, 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 for a Ph.D. 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, 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 five years or less. Courses are normally taken only the first two years, but seminars are a rich source of new knowledge during 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 a feeling of 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

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

The Bachelor of Science Degree in Chemistry is intended for students who are primarily interested in careers as professional chemists.

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.

Both 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. Certification of graduates is determined by the college at the time of graduation.

Additional information on ACS certification is available in the Undergraduate Affairs Office, 420 Latimer Hall.

The Bachelor of Science Degree

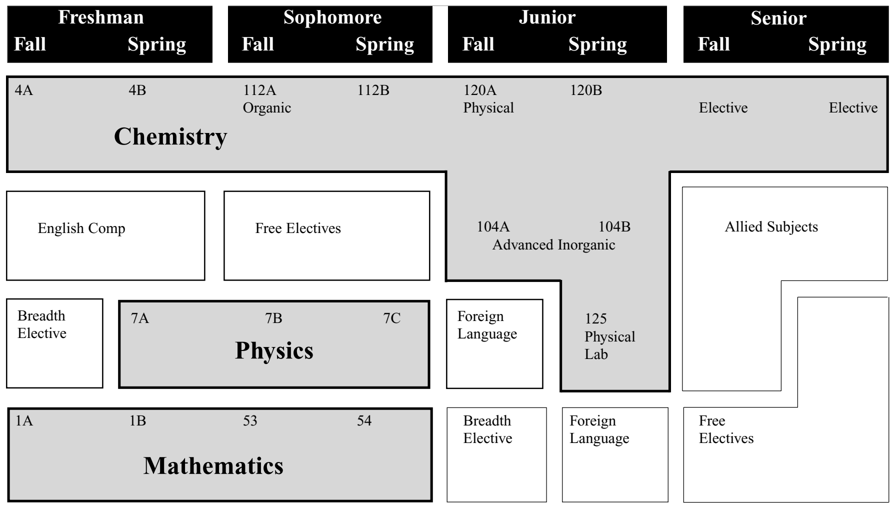
To graduate with a B.S. degree, the student must have satisfactorily completed a *minimum of 120 units* and also have satisfied the specific lower division and upper division requirements. In addition, the student must fulfill the scholarship requirements specified in the “Academic Requirements” section of this announcement (see Table of Contents).

Lower Division

The suggested course program for the first two years may be taken at Berkeley, at one of the community colleges in the state, or at another accredited institution.

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

Representative Undergraduate Chemistry Program



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, which they should take during their freshman year. Students study organic chemistry during their sophomore year by taking the 112A-112B sequence. (Note that a grade of C- or better is required in Chemistry 4A before taking 4B, in Chemistry 4B before taking more advanced courses, and in Chemistry 112A before taking 112B.)

[2]**Mathematics.** 1A, 1B, 53, and 54. This program should start in the first semester of the freshman year.

[2]**Physics.** 7A, 7B, 7C. This program should start in the second semester of the freshman year.

Subject A. The University assumes that you are proficient in English and in writing about academic topics. Fulfillment of the Subject A requirement is a prerequisite to enrollment in all freshman reading and composition courses. If you have not passed the Subject A examination or otherwise fulfilled the requirement when you enter the University, you should enroll in College Writing 1A during your first or second semester. College Writing 1A is a 6-unit course that satisfies the Subject A requirement and a first-level English composition course (e.g., English 1A). Detailed information about this general University requirement is available in the *General Catalog.*

English Composition and Literature. 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; Group I, English Composition and Literature.” The first-level and second-level courses need not be from the same department. Students *who begin their studies at Berkeley in fall 1999 or thereafter* are required to take the English composition courses on a letter-graded basis.

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 office for verification of course acceptance. After admission to Berkeley, credit for English at another institution will not be granted if the Subject A requirement has not yet been satisfied.

[1,3]**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. (Students *who begin their studies at Berkeley in fall 1999 or thereafter* are required to take the English composition courses on a letter-graded basis.) 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 list in the General Information section of this publication.

[1]May be taken on P/NP basis

[2]It is particularly important for students who plan to transfer to the college as juniors to take adequate mathematics and physics in their first two years. Lack of sufficient mathematics and physics will delay taking physical chemistry in the junior year.

[3]Need not be completed before entering the junior year.

[1]American Cultures. The American cultures breadth requirement is satisfied by passing, with a grade not lower than C- or P, an American cultures course. See the *Schedule of Classes* for the specific American cultures courses offered each semester. Detailed information about this Berkeley campus requirement is available in the *General Catalog* or on the web site at learning.berkeley.edu/AC.

[1]American History and Institutions. The American History and Institutions requirements are normally satisfied by high school work with sufficiently high grades in these subjects. Detailed information about these general University requirements is available in the *General Catalog* or on the web site at learning.berkeley.edu/ahi.

[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).

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

[2]It is particularly important for students who plan to transfer to the college as juniors to take adequate mathematics and physics in their first two years. Lack of sufficient mathematics and physics will delay taking physical chemistry in the junior year.

[3]Need not be completed before entering the junior year.

The following program is suggested for the first two years:

Suggested Lower Division Program for Chemistry

		Units
Freshman Year	*Fall*	*Spring*
Chemistry 4A-4B	4	4
Chemistry C96	1	-
Mathematics 1A-1B	4	4
Physics 7A	-	4
English Composition[1]	4	4
Breadth Elective[1]	3- 4	-
Total	**16-17**	**16**
Sophomore Year		
Chemistry 112A-112B	5	5
Mathematics 53, 54	4	4
Physics 7B-7C	4	4
Free Elective	3	3
Total	**16**	**16**

Upper Division

During the junior and senior years the following course requirements must be completed:

Chemistry. 104A, 104B, 120A, 120B, 125 and *one* of the following choices: 105, 108, 115, or 146.

(Note that a grade of C- or higher is required in Chemistry 120A and/or 120B if taken before 125.)

11 Units of Upper Division Chemistry and Allied Subjects. *In addition to the requirements listed above,* the following must be completed to total at least 11 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 Suggested Allied Subject Courses that follows this section.

Note: Courses taken in satisfaction of this requirement must be upper division with the exception of Biology 1A, if completed with a grade of C- or better.

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 11-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 11-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.

Suggested Allied Subject Courses

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

Biology
1A or 1B (but not both)

Note: Biology 1A or 1B must be completed with a grade of C- or better to be counted as an allied subject.

Chemical Engineering
140, 141, 142, 150A, 150B, 154, 157, 160, 162, 170, 170E, 170L, 171, 173, 175, 176, 178, 179, 181, H194, 195, 196

Chemistry
100, 105, 108, 113, 115, 122, 135, 143, 146, 192, H194, 195, 196

Note: If a course is used to satisfy another requirement (such as the 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, 110, 111, 112, 114, 115, 115L, 116

Computer Science
150, 152, 160, 162, 164, 170, 174, 184

Earth and Planetary Science
103, 105, 106, 131, 203

Education
223B, 224A

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

Electrical Engineering
100

Energy and Resources Group
102, 120, C130, 140, 141

Engineering
102, 117, 118, 128

Environmental Science, Policy, and Management
119, 120, 126, 180

Integrative Biology
106A

Materials Science
100, 102, 103, 104, 111, 112, C113, 114, 115, 116, 117, C118, 120, 121, 122, 123, 124, 125, 130A, 160, 161, 176

Mathematics
C103, 104, H104, 105, 110, H110, 113, H113, 114, 115, H117, 119, 121A, 121B, 123, 125A, 125B, 126, 128A, 128B, 130, 135, 140, 142, 160, 170, 185, H185, 187, 189

Molecular and Cell Biology
100, 102, 110, 110L, 111, C112, 113, C114, 115, C116, 140

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

Nutritional Sciences and Toxicology
103, 110, 113, 150, 160

Physics
105, 110A, 110B, 137B, 141A, 141B, 150

Plant and Microbial Biology
C102, C102L, C107, C107L, 110, 110L, C111, C111L, C112, C114, C116, 120, 120L, 135, 135L, 150, 150L, 160, 160L, 170, 180

Public Health
C171, 172

Statistics
101, 102, 134, 135

Individual Major in Chemical Biology

The College of Chemistry offers an individual major in chemical biology leading to a Bachelor of Science degree. The chemical biology major is intended to provide a solid background in chemistry as it affects areas like biochemistry, molecular biology, bioengineering, structural biology, drug design, pharmacology, and medicine. Students who are interested in the individual major in chemical biology may obtain additional information by contacting the Undergraduate Majors Office.

The Bachelor of Arts Degree

To graduate with a B.A. degree, 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 (or 1A, 1B and 5); 104A, 104B, 112A, 112B, 120A, 120B, and a choice of one of 105, 108, 125. (Note that a grade of C- or better is required in Chemistry 1A or 4A before taking 1B or 4B, in Chemistry 1B or 4B before taking more advanced courses, in Chemistry 112A before taking 112B, and in Chemistry 120A and/or 120B if taken before 125.)

Mathematics. 1A, 1B, and 54. Math 53 is strongly recommended.

Physics. 7A, 7B, 7C.

Honors at Graduation

Upper division students may be admitted to the honors program (Chemistry H194) if they have an overall Berkeley grade-point average of at least 3.4. To be eligible to receive honors in chemistry, candidates for the B.A. degree must (1) earn a grade-point average of at least 3.5 in upper division courses in the major and at least 3.3 overall at Berkeley; and (2) complete at least 3 units of Chemistry H194 or another advanced chemistry course as approved by the department.

Chemistry Minor

A minor in chemistry will be awarded to students who have successfully completed one year of organic chemistry (3A-3B or 112A-112B or equivalent), one year of physical chemistry taken at Berkeley (120A-120B or 130A-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, 3B, 112A, or 112B. For the minor to be awarded, students must submit a notification of completion of the minor at 420 Latimer Hall.

Note: Consult with your college/school for information on rules regarding overlap of courses between the student's major and minor.

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 8 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 an opportunity to develop a more extensive preparation and training in their chosen professional field.

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 three to five 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. The Chemistry Department graduate study brochure contains detailed information about research, and all prospective Ph.D. students are encouraged to send for this information at the start of their senior 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.

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 nuclear chemistry, biophysical, bio-organic and bio-inorganic, and space and atmospheric chemistry.

Analytical Chemistry

Analytical and bioanalytical chemistry has undergone explosive growth in recent years due to fast-growing 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 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. 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 DNA sequencing and DNA 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 and Biological Chemistry

A number of Berkeley faculty are applying combinations of physical, organic, and biochemical methods to the study of biological phenomena. Research directions encompass determination of structure and function of biomolecules, analysis of folding, signaling and reaction pathways, as well as dynamics and thermodynamics of the assembly of complex arrays or proteins, nucleic acids and membranes. New, modified biomolecules are being made with chemical and biochemical methods including generation of libraries, in vivo selection schemes, and unnatural amino acid incorporation.

Systems being studied include signaling proteins, genetic regulatory proteins, enzymes, DNA and RNA. Structures are determined with X-ray and electron diffraction and NMR and EPR spectroscopies. Function is probed with mutagenesis, following activity and spectroscopic changes. The structures are used to design inhibitors of many types. Berkeley is well equipped for structural work, including a 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 phototechnical isomerizations (such as occur during vision), electron transfer processes, and photochemical 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.

Progress is being made throughout this field by combining new ideas in chemistry with advances in biochemistry and molecular biology. Within chemistry the disciplines of physical, organic, and analytical chemistry all contribute valuable ideas of enhance understanding of complex biological systems.

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, ultra-low temperature nuclear orientation, theoretical studies of nuclear structure and reactions, as well as related atomic and molecular research in photoelectron spectroscopy (ESCA), X-ray crystallography, X-ray production in heavy ion collisions, X-ray fluorescence, hot-atom chemistry, and neutron and charged particle activation analysis.

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, and novel polymers. Advanced solid-state materials such as superconductors, semiconductors, and charge-transporting polymers are prepared by novel synthetic routes. Structural 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; multiple-pulse spectroscopy; photoelectron spectroscopy; molecular beams; low-energy electron diffraction; X-ray diffraction; picosecond laser spectroscopy; high-resolution and solid state NMR, ESR and optical spectroscopy; chemical synthesis; the measurement of thermodynamic and transport properties; sum frequency generation-surface vibrational spectroscopy; scanning tunneling microscope; atomic force microscope; and raman spectroscopy. 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, molecules in molecular crystals, intercalation compounds, metal and polymer surfaces and adsorbed layers; molecular studies of friction and lubrication; 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; electrical, magnetic, and thermodynamic properties of novel materials.

Theoretical Chemistry

Theoretical chemistry at Berkeley covers a broad spectrum of the discipline. Experiments are done 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, collision dynamics and chemical 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. 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, ideal and real gases, acid-base and solubility equilibrium, oxidation-reduction reactions, thermochemistry, introduction to thermodynamics, nuclear chemistry and radioactivity, the atoms and elements, and the periodic table. Laboratory sections focusing on environmental chemistry are available. See the *Schedule of Classes* for details. *(F, S)*

1B. General Chemistry. (4) Courses 3A and 4B will restrict credit if completed before 1B. Two hours of lecture, one hour of discussion, and four hours of laboratory per week. *Prerequisites: 1A or a score of 3, 4, or 5 on the Chemistry AP test.* Chemical bonding, molecular structure, introduction to chemical kinetics, qualitative analysis and descriptive chemistry, introduction to organic chemistry. Special topics: Research topics in modern chemistry and biochemistry, physical chemistry, nuclear chemistry, inorganic chemistry and chemical engineering. *(S)*

3A. Chemical Structure and Reactivity. (5) Courses 1B, 4B, and 112A will restrict credit if completed prior to 3A. Three hours of lecture, one hour of discussion, and four hours of laboratory per week. *Prerequisites: 1A with a grade of C- or higher, or a score of 4 or 5 on the Chemistry AP test.* Introduction to chemical structures, bonding, chemical reactivity, and organic chemistry (alkanes, alkyl halides, alcohols, alkenes, alkynes, carbonyl compounds and organometallics). *(F, S)*

3B. Chemical Structure and Reactivity. (4) Course 112B will restrict credit if completed prior to 3B. Three hours of lecture and four hours of laboratory per week. *Prerequisite: 3A with a grade of C- or better.* Carboxylic acids and amines, difunctional compounds, amino acids, peptides, carbohydrates, benzene chemistry, 3rd row elements, transition metals, electrochemistry. Wherever possible, examples will be drawn from biological chemistry. *(F, S)*

4A-4B. General Chemistry and Quantitative Analysis. (4;4) Courses 1A, 1B, and 5 will restrict credit if completed prior to 4A-4B. Three hours of lecture and four hours of laboratory per week. *Prerequisites: High school chemistry and calculus (may be taken concurrently). High school physics is recommended.* 4A-4B is intended for majors in the chemical sciences. This series presents the 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 5 as prerequisite for further courses in chemistry. *4A (F); 4B (S)*

5. Quantitative Analysis. (3) Course 4B will restrict credit if completed prior to 5. Two hours of lecture and four hours of laboratory per week. *Prerequisite: 1A or a score of 5 on the Chemistry AP exam; 1B or 3A is recommended. A minimum grade of C- is required in 1A, 1B, or 3A.* Acid-base, redox, complex formation equilibria and their applications to volumetric analytical methods. Principles and applications of spectrophotometry, potentiometry, coulometry, polarography, and ion exchange chromatography. Selected additional topics in instrumental analysis. *(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. *(S)*

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. *(F, S)*

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. *(F, S)*

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 or Chemical Engineering major or consent of instructor. Chemistry 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. *Prerequisites: 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, prepare oral and written reports. *(S)*

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)*

104A-104B. Advanced Inorganic Chemistry. (3;3) 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. *(F, S)*

105. Instrumental Methods of Analysis. (4) Two hours of lecture and two 4-hour laboratories per week. *Prerequisites: 4B or 5.* Principles and applications of spectroscopic, chromatographic, and electrochemical methods including atomic spectroscopy, mass spectrometry, gas chromatography, surface characterization methods, and voltammetric techniques. Discussion of instrument design and capabilities. Hands-on laboratory work emphasizing independent projects involving real-life samples. *(F)*

108. Inorganic Synthesis and Reactions. (4) Two hours of lecture and eight hours of laboratory per week. *Prerequisites: 4B or 5; 104A with a grade of C- or higher; and 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) Courses 3A and 3B will restrict credit if completed prior to 112A-112B. Three hours of lecture, one hour of laboratory lecture, 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 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 Organic Chemistry. (3) Three hours of lecture per week. *Prerequisite: 112B or 3B.* Study of advanced topics of organic chemistry including linear free energy relations, orbital symmetry, mechanisms and complex synthesis, including heterocyclic systems. *(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)*

120A. Physical Chemistry. (3) Course 130B will restrict credit if completed before 120A. Three hours of lecture per week. *Prerequisites: 4B or equivalent; Mathematics 53; Physics 7B or 8B; Mathematics 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) Course 130A will restrict credit if completed before 120B. Three hours of lecture per week. *Prerequisites: 4B or equivalent; Mathematics 53; Physics 7B or 8B; Mathematics 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: 120B.* Postulates and methods of quantum mechanics and group theory applied to molecular structure and spectra. (F)

125. Physical Chemistry Laboratory. (3) One hour of lecture and one 5-hour laboratory per week. *Prerequisites: Two of 120A, 120B, 130A, 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)*

130A. Biophysical Chemistry. (3) Course 120B will restrict credit if completed prior to 130A. Two hours of lecture and one hour of discussion per week. *Prerequisites: 1B or 4B or 3A, and at least one semester course in calculus. Intended for students majoring in the biological sciences.* The weekly one-hour discussion is for problem solving and the application of calculus in physical chemistry. Bioenergetics, equilibrium and non-equilibrium states, molecular distributions, active and passive transport, reaction rates and mechanisms, enzyme reactions. *(F, S)*

130B. Biophysical Chemistry. (3) Courses 120A and 120B will restrict credit if completed prior to 130B. Two hours of lecture and one hour of discussion per week. *Prerequisite: 130A 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; plus 130A (may be taken concurrently) or 4B; or consent of instructor.* One-semester introduction to biochemistry, aimed toward chemistry majors. *(F)*

143. Nuclear Chemistry. (2) Two hours of lecture per week. *Prerequisites: Physics 7C 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) Formerly 144. One 1 1/2-hour lecture and one 4 1/2-hour laboratory per week. *Prerequisites: 4B or 5; 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)*

C170L. Biochemical Engineering Laboratory. (3) Six hours of laboratory and one hour of lecture per week. *Prerequisites: Chemical Engineering 170 or 170E (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. *(S)*

C182. Atmospheric Chemistry and Physics Laboratory. (3) 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)*

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. *Prerequisite: Consent of instructor and adviser.* Special laboratory work for advanced undergraduates. *(F, S)*

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. *Prerequisites: Graduate standing or consent of instructor.* Review of bonding, structure, stereochemistry, conformation, thermodynamics and kinetics, and arrow-pushing formalisms. *(F)*

201. Fundamentals of Inorganic Chemistry. (1) Three hours of lecture per week for five weeks. *Prerequisites: 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 1-hour lectures and two 4-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 1-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. *(S)*

220B. Statistical Mechanics. (3) Three 1-hour lectures per week. *Prerequisite: 220A.* Principles of statistical mechanics and applications to complex systems. *(F)*

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)*

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. *(F)*

223B. Chemical Dynamics. (3) Three hours of lecture per week. *Prerequisites: 221A and 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. *(S)*

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. *(S)*

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. *Prerequisites: 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. *Prerequisites: 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. *Prerequisites: 251A or consent of instructor.* Synthesis, structure analysis, and reactivity patterns in terms of symmetry orbitals. *(S)*

252A. Organometallic Chemistry I. (1) Three hours of lecture per week for five weeks. *Prerequisites: 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. *Prerequisites: 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. *(S)*

253B. Materials Chemistry II. (1) Three hours of lecture per week for five weeks. *Prerequisites: 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. *(S)*

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)*

255. Advanced Analytical Chemistry I. (3) *Formerly 250.* Three hours of lecture per week. *Prerequisites: Graduate standing or consent of instructor.* State-of-the-art techniques in modern analytical chemistry will be presented in areas including mass spectrometry, electrochemistry, and separations. Emphasis will be on instrumentation, methods, detection, and recent applications. *(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. *(S)*

260A. Reaction Mechanisms I. (1) Three hours of lecture per week for five weeks. *Prerequisites: 200 or 201 or consent of instructor.* Thermochemistry, acidity, bond energies, mechanistic analysis, MO theory and aromaticity, kinetics and isotope effects. *(F)*

260B. Reaction Mechanisms II. (1) Three hours of lecture per week for five weeks. *Prerequisites: 260A or consent of instructor.* Reactive intermediates, photochemistry, solvent and substituent effects. *(F)*

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

262. Metals in Organic Synthesis. (1) Three hours of lecture per week for five weeks. *Prerequisites: 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. *Prerequisites: 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, terpens, 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. *Prerequisites: 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. *(S)*

264A. Synthesis of Macromolecules. (1) Three hours of lecture per week for five weeks. *Prerequisites: 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 crosslinked networks. *(S)*

264B. Properties and Applications of Macromolecules. (1) Three hours of lecture per week for five weeks. *Prerequisites: 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. *(S)*

265. Nuclear Magnetic Resonance Theory and Application. (1) Three hours of lecture per week for five weeks. *Prerequisites: 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. *Prerequisites: 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. *(S)*

267. Organic Specialties. (1) Three hours of lecture per week for five weeks. *Prerequisites: 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. *(S)*

270A. Advanced Biophysical Chemistry I. (1) Three hours of lecture per week for five weeks. *Prerequisites: 200 or consent of instructor.* Underlying principles and applications of methods for biophysical analysis of biological macromolecules. *(F)*

270B. Advanced Biophysical Chemistry II. (1) Three hours of lecture per week for five weeks. *Prerequisites: 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. *Prerequisites: 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. *Prerequisites: 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. *Prerequisites: 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. *Prerequisites: 270A-270B or consent of instructor.* Theory and application of X-ray crystallography to biomacromolecules. *(S)*

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

273A. Bio NMR I. (1) Three hours of lecture per week for five 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 multidimensional NMR in probing structure, interactions, and dynamics of biological molecules will be described. *(S)*

273B. Bio NMR II. (1) Three hours of lecture per week for five 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. *(S)*

295. Special Topics. (1-3) Course may be repeated for credit. Must be taken on a *satisfactory/unsatisfactory* basis. *Prerequisites: 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 bioorganic 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 a member 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) 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. Formerly 301.* 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 8 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 1A-1B or 112A-112B. Students attend a weekly meeting with instructors. *(F, S)*

Administration and Faculty

General Administrative Officers

President of the University
Richard C. Atkinson, Ph.D. *(until October 1, 2003; afterward, to be announced)*

Chancellor, Berkeley
Robert M. Berdahl, Ph.D.

The Executive Vice Chancellor and Provost
Paul R. Gray, Ph.D.

Dean of the Graduate Division, Berkeley
Mary Ann Mason, Ph.D.

College of Chemistry Administration

Dean
Clayton H. Heathcock, Ph.D.

Associate Dean (Undergraduate Affairs)
Herbert L. Strauss, Ph.D.

Assistant Dean (Services)
K. Peter C. Vollhardt, Ph.D.

Assistant Dean (College Relations)
Jane L. Scheiber, A.B.

Faculty of the Department of Chemical Engineering

Professors
Nitash P. Balsara, Ph.D.
Alexis T. Bell, Sc.D.
Harvey W. Blanch, Ph.D.
Elton J. Cairns, Ph.D.
Arup K. Chakraborty, Ph.D. *(Chair)*
Douglas S. Clark, Ph.D.
David B. Graves, Ph.D. *(Vice Chair)*
Enrique Iglesia, Ph.D.
Jay D. Keasling, Ph.D.
C. Judson King, Sc.D.
Roya Maboudian, Ph.D.
Susan J. Muller, Ph.D. *(Vice Chair)*
John S. Newman, Ph.D.
John M. Prausnitz, Ph.D., Dr. Ing., Sc.D.
Clayton J. Radke, Ph.D.
Jeffrey A. Reimer, Ph.D.
LeRoy A. Bromley, Ph.D. *(Emeritus)*
Morton M. Denn, Ph.D. *(Emeritus)*
Alan S. Foss, Ph.D. *(Emeritus)*
Simon L. Goren, D.Eng. *(Emeritus)*
Edward A. Grens, Ph.D. *(Emeritus)*
Donald N. Hanson, Ph.D. *(Emeritus)*
Scott Lynn, Ph.D. *(Emeritus)*
David N. Lyon, Ph.D. *(Emeritus)*
Eugene E. Petersen, Ph.D. *(Emeritus)*
Charles R. Wilke, Ph.D. *(Emeritus)*
Michael C. Williams, Ph.D. *(Emeritus)*

Assistant Professors
Alexander Katz, Ph.D.
David V. Schaffer, Ph.D.
Rachel A. Segalman, Ph.D.

Lecturers
Arnold L. Grossberg, M.S.
Paul B. Plouffe, Ph.D.
Moshe Sternberg, Ph.D.
P. Henrik Wallman, Ph.D.

Faculty of the Department of Chemistry

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

Professors
A. Paul Alivisatos, Ph.D. *(Materials Science)*
Richard A. Andersen, Ph.D.
John Arnold, Ph.D.
Paul A. Bartlett, Ph.D.
Robert G. Bergman, Ph.D.
Carolyn R. Bertozzi, Ph.D. *(Vice Chair) (Cellular and Molecular Pharmacology, UCSF)*
Carlos J. Bustamante, Ph.D. *(Physics, Molecular and Cell Biology)*
Joseph Cerny, Ph.D.
Arup K. Chakraborty, Ph.D. *(Chemical Engineering)*
David Chandler, Ph.D
Jennifer Doudna, Ph.D.
Jonathan Ellman, Ph.D. *(Vice Chair), (Cellular and Molecular Pharmacology, UCSF)*
Graham R. Fleming, Ph.D.
Jean M. J. Fréchet, Ph.D.
Charles B. Harris, Ph.D. *(Chair)*
Robert A. Harris, Ph.D.
Martin Head-Gordon, Ph.D.
Clayton H. Heathcock, Ph.D.
Sung-Hou Kim, Ph.D.
Jack F. Kirsch, Ph.D. *(Molecular and Cell Biology)*
Judith P. Klinman, Ph.D. *(Molecular and Cell Biology)*
John Kuriyan, Ph.D.
Stephen R. Leone, Ph.D.
William A. Lester, Jr., Ph.D.
Marcin M. Majda, Ph.D. *(Vice Chair)*
Michael A. Marletta, Ph.D.
Richard A. Mathies, Ph.D.
William H. Miller, Ph.D.
Luciano G. Moretto, Ph.D.
Daniel M. Neumark, Ph.D.
Heino Nitsche, Ph.D.
Alexander Pines, Ph.D.
Kenneth N. Raymond, Ph.D.
Richard J. Saykally, Ph.D.
Charles V. Shank, Ph.D. *(Physics, EECS)*
Kevan Shokat, Ph.D. *(Cellular and Molecular Pharmacology, UCSF)*
Angelica M. Stacy, Ph.D. *(Vice Chair)*
Herbert L. Strauss, Ph.D.
T. Don Tilley, Ph.D.
K. Peter C. Vollhardt, Ph.D.
David E. Wemmer, Ph.D.
K. Birgitta Whaley, Ph.D.
Evan R. Williams, Ph.D.
Neil Bartlett, Ph.D. *(Emeritus)*
Leo Brewer, Ph.D. *(Emeritus)*
James Cason, Jr., Ph.D. *(Emeritus)*
Robert E. Connick, Ph.D. *(Emeritus)*
John E. Hearst, Ph.D. *(Emeritus)*
Darleane C. Hoffman, Ph.D. *(Emeritus)*
Harold S. Johnston, Ph.D. *(Emeritus)*
William L. Jolly, Ph.D. *(Emeritus)*
Samuel S. Markowitz, Ph.D. *(Emeritus)*
C. Bradley Moore, Ph.D. *(Emeritus)*
Rollie J. Myers, Ph.D. *(Emeritus)*
Donald S. Noyce, Ph.D. *(Emeritus)*
Chester T. O'Konski, Ph.D. *(Emeritus)*
Norman E. Phillips, Ph.D. *(Emeritus)*
John O. Rasmussen, Ph.D. *(Emeritus)*
Kenneth Sauer, Ph.D. *(Emeritus)*
David A. Shirley, Ph.D. *(Emeritus)*
Andrew Streitwieser, Jr., Ph.D. *(Emeritus)*
David H. Templeton, Ph.D. *(Emeritus)*
Ignacio Tinoco, Jr., Ph.D. *(Emeritus)*

Associate Professor
Ronald C. Cohen, Ph.D. *(Earth and Planetary Science)*

Assistant Professors
Adam Arkin, Ph.D. *(Bioengineering)*
Kristie A. Boering, Ph.D. *(Earth and Planetary Science)*
Jamie Cate, Ph.D.
Matthew Francis, Ph.D.
Jay T. Groves, Ph.D.
Jeffrey Long, Ph.D.
F. Dean Toste, Ph.D.
Dirk Trauner, Ph.D.
Haw Yang, Ph.D.
Peidong Yang, Ph.D.

Adjunct Professors
Julie Leary, Ph.D.
C. William McCurdy, Ph.D.

Lecturers
Michelle Douskey, Ph.D.
Ahamindra Jain, Ph.D.
Mark Kubinec, Ph.D.
Kimberly Lavoie, Ph.D.
Steven Pedersen, Ph.D.

Breadth Requirement Course List

Group I (English Composition and Literature)

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

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

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

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

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)

German
R5A-R5B. Reading and Composition (4-4)

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

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

Near Eastern Studies
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
R5A-R5B. Reading and Composition (4-4)

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

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

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

Undergraduate and Interdisciplinary Studies (UGIS)
Each 5-unit course satisfies either the first level or the second level of the English Composition requirement.
R44A-R44B. Topics in Western Civilization (5-5)
R44C. Topics in Western Civilization (5) (5-unit sections only)
R55A-R55B. The Development of World Civilization (5-5)

Women's Studies
R1A. Freshman Composition (4)
R1B. Reading and Composition (4)

Completion of College Writing R1A with a grade of C- or better satisfies Subject A and the first level of the English composition requirement. Only 4 units (of the 6) are accepted toward the breadth requirement.

The following writing-intensive courses are considered equivalent to English R1B: Linguistics 5 plus R5W (6 units total); Slavic R37W (5 units); 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 2-unit courses. Exception: In general, you may not use courses numbered 98, 99, or above 190 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 advanced technical elective or an allied subject). 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
2

African American Studies
4A-29AC, 100-117, 121-138, 139*, 142A-C175

Afrikaans
10, 150

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

Anthropology
2, 3, 3AC, 10AC-18, 72-74, 94, 106, 109, 111, 114-119, 121A-C, 122A-122F, 123A-123E, 124A, 124AC, 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, 122, 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
10A, 10B, 147, 148, 149, 150

Buddhism
181, 182, 183

Business Administration (UGBA)
10, 39AC, 111, 112, 150, 154, 155, 156, 170, 171, C172, 175, 187, 188

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

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

Chinese
1A, 1B, 2A, 2B, 5, 10A, 10B, 100A, 100B, 101, 102, 120, 122, 130, 132, 134, 136, 140, 142, 155, 156, 157, 161, 163, 165, 169, 181A, 181B, 183, C185, 188

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

Civil and Environmental Engineering
151, 167

Classics
10A, 10B, 17A, 17B, 28, 29, 30B, 34, 35, 36, 100A, 100B, 110, 121, 124, 130, 132, 155A, 155B, 161, 163, 170A, 170B, 170C, 170D, 175A, 175B, 175C, 175D, 175E, 175F, 180

Cognitive Science
C1, C100, C101, C102, C108, C110, 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, 164, 165, 166, 170, 175, 177

Economics
any

Education
C1, 40AC, 50, 75, 100, 103, 113, 114A, 114B, 114C, C122, 124, 130, 140, 141, C144, C145, C147, 169, 170, 180, 181, 183, 184, 186AC, 187, 188, 189, 190

Egyptian
any

Energy and Resources Group
100, 102, 141, 151, 162, 190

Engineering
120, 191, 195

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

Environmental Design
1, 4, 71, C169A, C169B

Environmental Economics and Policy
1, 2, 100, 101, C115, 118, 141, 142, C151, 152, 161, 162

Environmental Science, Policy, and Management
10, 11, C12, 50AC, 60, 100, 101E, 102A, 102B, 102C, 102D, C103, 136, 153, 154, 155, C159, 161, 162, 164, 165, 166, 167, 182, 183, 184, 185, 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

Film Studies
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

Geography
4-35, 50AC-138, 150AC-159AC, C160A, C160B, 162, 163, 165-169, 180, 181, 189

German
1, 2, 3, 4, 25, 40, 100-102, 105, C106, C109-123, 130, 132-143, 150-162, 164, 165, 168-171, 175C, 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 Management and Systems
101, 138, 142AC, 182AC

Integrative Biology
C156

Interdepartmental Studies
1, 100AC, 114A, 114B, 130, 145, 156AC, 170, 180, 182

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

International and Area Studies
45, 102, 120, C142, 143, C145, 150

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, 120, 130, 132, 134, 140, 142, 144, 146, 155, 159, 162, 164, 182A, 182B, 183, 184, 185, 186

Journalism
140, 141, 151, 158, 163, C165, 175, C177, 180, C183

Korean
1A, 1B, 10A, 10B, 100A, 100B, 101, 102, 150, 155, 160, 187A, 187B

Landscape Architecture
101, 102, 103, 110, 111, 121, 130, 131AC, 134A, 134B, 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, 116, 118, 120, 122

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
any, except 20A, 20B, 25A, 25B, 108, 116, 117, 140, 163 (see note below)

Native American Studies
71, 72, 90, 100, 101, 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
10-92, 101A-107, 109, 110, 120A-174

Nutritional Sciences and Toxicology
104, 135, C159

Peace and Conflict Studies
10, 100, 125AC, 127A, 127B, 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 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, 100A, 101-110, 120A, 120B, 123-125AC, C129-142, 146-168, 180, 182, C191

Public Health
14, 103, 105, 106, 114, 130AC, 150A, 150B, 150C, 150E, 180, 190

Public Policy
1, 6, 101, 117AC, 156, 159-171, 173-188

Religious Studies
90A, 90B, C103, C104, C108, C109, C111, 115, 120A, 120B, 123, C124, 125, 130, C132, C133, C156, C157, C161, C162, 163, C165, C166, 171AC, 172AC, C175, C182, C183, 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

Scandinavian
1A, 1B, 2A, 2B, 3A, 3B, 4A, 4B, 12, 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, 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 Asian
1A, 1B, 108, 121, C127, C128, 129, 130, 138, 139, C140, 141, C142, 143, 145, 155

South and Southeast Asian Studies
138

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

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

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, 149, 160, 162, 166*, 170, 172, 173A-176, 177, 181

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

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

Undergraduate and Interdisciplinary Studies
C12, C14, 20AC, R44A, R44B, R44C, R55A, R55B, 56AC, C92, 110, 112, 114, 121, C130, C132, C133, C134, C135, C136, C137, C145, C146, C147B, C152, C154, 170

Visual Studies
180A, 180B, 185A, 185X, 189

Women's Studies
10, 12, 14, C15, 20, R20W, 40, 50AC, 100AC, 101, 102, 103, 104, 111, 112, 113, 120, C122, 125, 131, C136, 139, 140, 141, C142, C145, C146, C153A, C153B

Yiddish
1, 2

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 6 units of foreign language may be counted toward the 19-unit breadth requirement.

• For the chemistry 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 or Institutions requirements will be accepted toward satisfaction of the breadth requirement. Students can petition for acceptance of a freshman seminar course.

If you would like to take a course that does not appear on this list and you feel that the course should count toward the breadth requirement, check with your staff adviser.

ADVANCED PLACEMENT TESTS — CREDIT INFORMATION

Name of Test (*Credit granted by UC)	Score	UC Berkeley Course(s) (or Requirements) Satisfied
Chemistry (5.3 units)	3 or higher	none
****Math:** **Calculus AB** **Calculus AB SUB** (2.7 units)	3 4 or 5	none 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	Subject A ***Subject A **and** a first-level English composition course (e.g., English 1A) with 4 units of credit toward the Breadth Requirement (Group I) ***Subject A **and** first- and second-level English composition courses (e.g., English 1A and Rhetoric 1B) with 5.3 units of credit total toward the Breadth Requirement (Group I)
****English** **Language & Composition** (5.3 units)	3 4 or 5	Subject A ***Subject A **and** a first-level English composition course (e.g., English 1A) 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)

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** 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** 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** majors, each test satisfies either the foreign lanuage 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 or higher	Does not satisfy any college/major requirement Note: With a score of 4 or 5, students receive subject credit for Biology 1A and 1B as prerequisite to other courses. Some areas of chemical engineering and chemistry require biology as a prerequisite to upper division electives. 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 & Composition and the English Language & 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.

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

**** For the **chemistry** 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.

Nondiscrimination Statement

The University of California, in accordance with applicable federal and state law and University policy, prohibits discrimination, including harassment, on the basis of race, color, national origin, religion, sex, physical or mental disability, medical condition (cancer-related or genetic characteristics), ancestry, marital status, age, sexual orientation, citizenship, or status as a covered veteran (special disabled veteran, Vietnam-era veteran or any other veteran who served on active duty during a war or in a campaign or expedition for which a campaign badge has been authorized). This nondiscrimination policy covers admission, access, and treatment in University programs and activities. Inquiries may be directed as follows: Sex discrimination and sexual harassment: Nancy Chu, Title IX Compliance Officer, (510) 643-7985; disability discrimination and access: Ward Newmeyer, A.D.A./504 Compliance Officer, (510) 643-5116 (voice) or (510) 642-3172 (TTY/TDD); age discrimination: Alan T. Kolling, Age Discrimination Act Coordinator, (510) 642-8471. Other inquiries may be directed to the Academic Compliance Office, 200 California Hall #1500, (510) 642-2795.

Student Right to Know Act

The University of California, Berkeley, maintains a reference guide of safety information and procedures, annual campus crime statistics, and emergency/disaster preparedness information. For a copy of this report, "Safety Counts," call, e-mail, or write the Police Department Campus Safety Programs, (510) 643-6442, ucpolice@uclink.berkeley.edu, or University of California Police Department, Attn. Campus Safety Programs, 1 Sproul Hall, Berkeley, CA 94720-1199. You also can find the report on the Campus Safety Programs Web site at http://public-safety.berkeley.edu/csp/.

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