

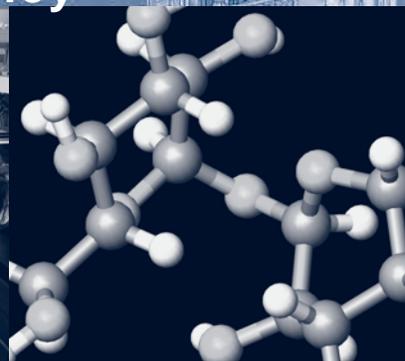
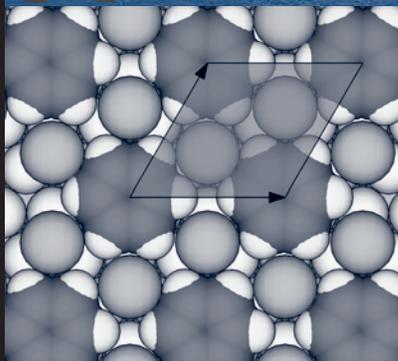
2012-2013

College of Chemistry

# Guide

to Undergraduate Studies in  
Chemistry,  
Chemical Engineering, and  
Chemical Biology

University of California, Berkeley



---

**Academic Calendar****2012-13**

---

**Fall Semester 2012**

Tele-BEARS Begins	April 9	Monday
Fee Payment Due	August 15	Wednesday
Fall Semester Begins	August 16	Thursday
Welcome Events	August 20-24	Monday-Friday
Instruction Begins	August 23	Thursday
Labor Day Holiday	September 3	Monday
Veterans Day Holiday	November 12	Monday
Thanksgiving Holiday	November 22-23	Thursday-Friday
Formal Classes End	November 30	Friday
Reading/Review/Recitation Week	December 3-7	Monday-Friday
Final Examinations	December 10-14	Monday-Friday
Fall Semester Ends	December 14	Friday
Winter Holiday	December 24-25	Monday-Tuesday
New Year's Holiday	December 31-January 1, 2013	Monday-Tuesday

---

**Spring Semester 2013**

Tele-BEARS Begins	October 15, 2012	Monday
Spring Semester Begins	January 15	Tuesday
Fee Payment Due	January 15	Tuesday
Martin Luther King Jr. Holiday	January 21	Monday
Instruction Begins	January 22	Tuesday
Presidents' Day Holiday	February 18	Monday
Spring Recess	March 25-29	Monday-Friday
César Chávez Holiday	March 29	Friday
Cal Day	April 20	Saturday
Formal Classes End	May 3	Friday
Reading/Review/Recitation Week	May 6-10	Monday-Friday
Final Examinations	May 13-17	Monday-Friday
Spring Semester Ends	May 17	Friday

---

**Summer Sessions 2013**

Tele-BEARS Begins	February 4	Monday
Memorial Day Holiday	May 27	Monday
First Six-Week Session	May 28-July 3	Tuesday-Wednesday
Ten-Week Session	June 10-August 16	Monday-Friday
Eight-Week Session	June 24-August 16	Monday-Friday
Independence Day Holiday	July 4	Thursday
Second Six-Week Session	July 8-August 16	Monday-Friday
Three-Week Session	July 29-August 16	Monday-Friday

---

**Contents**

<b>The College</b>	<b>To Prospective Students</b>	<b>3</b>
	<b>The College of Chemistry</b>	<b>5</b>
	<b>General Information</b>	<b>5</b>
	Living Environment	5
	Housing	5
	Student Activities	5
	Student Services	6
	Alumni, Development, and Public Affairs	6
	<b>Undergraduate Programs</b>	<b>7</b>
	Admission	7
	Degree Requirements	7
	Scholarship Requirements	8
	Academic Policies	9
	Academic Opportunities	10
<b>Department of Chemical and Biomolecular Engineering</b>	<b>Chemical Engineering as a Profession</b>	<b>12</b>
	<b>The Department of Chemical and Biomolecular Engineering (CBE)</b>	<b>12</b>
	<b>Undergraduate Programs</b>	<b>13</b>
	Lower Division Program	13
	Upper Division Program	14
	Additional Electives and Concentrations	14
	Representative Chemical Engineering Program for Transfer Students	15
	Joint Major Programs	15
	Chemical Engineering Minor	17
	Suggested Physical and Biological Science Courses	17
	Suggested Engineering Electives	17
	<b>Faculty Research Interests</b>	<b>18</b>
	<b>Courses</b>	<b>19</b>
	<b>Department of Chemistry</b>	<b>Chemistry as a Profession</b>
<b>The Department of Chemistry</b>		<b>24</b>
<b>Undergraduate Programs</b>		<b>25</b>
Choice of College and Major		25
The Bachelor of Science Degrees in Chemistry and Chemical Biology		25
Suggested Allied Subject Courses		27
The Bachelor of Arts Degree in Chemistry		27
Chemistry Minor		28
<b>Faculty Research Interests</b>		<b>28</b>
<b>Courses</b>		<b>30</b>
<b>General Information</b>		<b>Administration and Faculty</b>
	<b>College of Chemistry Breadth Requirement Course List</b>	<b>38</b>
	<b>Advanced Placement Tests — Credit Information</b>	<b>42</b>

Guide to Undergraduate Studies in Chemistry, Chemical Engineering, and Chemical Biology  
College of Chemistry, University of California, Berkeley, 2012-13.

Published by the College of Chemistry, University of California, Berkeley, 420 Latimer Hall #1460, Berkeley, CA 94720-1460. UC Berkeley home page: [berkeley.edu](http://berkeley.edu)

Although care is taken to ensure the accuracy of all information, there may be unintended errors and changes or deletions without notification. Fax: (510) 642-8369; College of Chemistry home page: [chemistry.berkeley.edu](http://chemistry.berkeley.edu)





## To Prospective Students

Chemistry, chemical biology, chemical engineering, and biomolecular engineering provide fantastic opportunities for pursuing a stimulating and gratifying career while making a positive impact on society. Since chemistry is the gateway to all the molecular sciences and much of engineering, our college facilitates many possible career paths. We live in a chemical world. Our lives, our environment, our energy, our food, and our products are all impacted and/or provided by the activities of chemists and chemical engineers. Making new organic, inorganic and nano materials; developing new drugs and methods for delivery; developing new synthetic procedures; understanding fundamental elements of chemical structure, bonding and reactions; exploring chemical biology, the chemical basis of biological processes; producing sustainable energy through biofuels and photovoltaics; and improving our environment through green chemical processes—all depend critically upon chemistry and chemical engineering. Students entering these fields today will find exciting careers addressing fundamental challenges in chemistry, applying chemical concepts to problems in related scientific areas, and using established concepts to pioneer new technologies.

The Department of Chemistry and the Department of Chemical and Biomolecular Engineering in the College of Chemistry rank among the most prominent in the nation, and both are renowned for their excellence in a diverse range of sub-disciplines and applications. Nowhere else will you find such a wide selection of instructional excellence in the chemical sciences and their applications, or such broad opportunities for research for both undergraduate and graduate students. Superb facilities at the Lawrence Berkeley National Laboratory enhance many of the college's research programs. The California Institute for Quantitative Biomedical Research (QB3) provides a dynamic interdisciplinary environment in which students and faculty in the college collaborate with their colleagues in the physical and biological sciences and in engineering to conduct cutting-edge research into biological problems and to produce the breakthroughs of the future.

With only two departments, the College of Chemistry provides a relatively small and collegial place in which to live and work, while being nestled in one of the most beautiful and vibrant cosmopolitan areas in the world. Your intellectual, scientific, and social experiences at Berkeley will shape your life and outlook for years to come.

We encourage you to explore our college's offerings and opportunities, and we look forward to your joining and experiencing UC Berkeley.

A handwritten signature in black ink that reads "Richard Mathies". The signature is written in a cursive style.

Richard Mathies  
Dean and Gilbert Newton Lewis Professor, College of Chemistry



SATHER GATE

ERECTED BY  
JANE K. SATHER  
M.D.C. 1911

IN MEMORY OF  
FREDERICK SATHER  
B.D. 1858

## 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 Department of Chemistry and the Department of Chemical and Biomolecular 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 108 faculty members are one Nobel laureate, five who have been honored with the National Medal of Science, 25 members of the National Academy of Sciences, seven members of the National Academy of Engineering, and 11 recipients of the Distinguished Teaching Award. 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 students have opportunities to do research in synthetic and structural chemistry of organic and inorganic compounds, chemistry of natural products, theoretical chemistry, nuclear chemistry, physical chemistry, organometallic chemistry, chemical biology, solid-state and surface chemistry, catalysis, process design and control, product development, polymers, food processing, and biochemical engineering.

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

## General Information

### Living Environment

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

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

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

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

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

## Housing

There is a wide variety of housing on and off the Berkeley campus. All new, incoming fall freshmen who apply for housing by the deadline are guaranteed housing in the residence halls. Admission to Berkeley does not guarantee housing reservations. Students should acquaint themselves well in advance of enrollment with the various living arrangements. Students may go to housing.berkeley.edu for more information or call (510) 642-4108.

## Student Activities

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

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

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

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

The activities of both the professional and the scholastic engineering societies are coordinated by the Engineering Student Council (ESC), which is made up of representatives from each group. Activities of ESC 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.

## 6 Student Services

The Berkeley campus offers student services in addition to those listed below. Visit [chemistry.berkeley.edu/student\\_info/undergrad\\_info/student\\_services.php](http://chemistry.berkeley.edu/student_info/undergrad_info/student_services.php) for a more extensive list of student services.

### Career Center/Recruiting

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

In addition to individual counseling, Career Center services include:

- on-campus recruiting program for graduating students with more than 350 employers participating;
- listings for full-time positions and student jobs and internships;
- career, internship/summer, and graduate school fairs; special workshops and programs for engineering students;
- mailing lists for receiving specialized career information;
- online and print materials for researching employers and graduate schools;
- web-based letter of recommendation service supporting application to graduate school or for academic employment; and
- graduate school admission test material.

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

### Berkeley Study Abroad

While progressing toward degrees in the College of Chemistry, undergraduates have opportunities to earn credit toward their degrees while studying abroad. College of Chemistry undergraduates are encouraged to participate in Berkeley Study Abroad.

For information about these programs contact an adviser in the Berkeley Study Abroad Office, University of California, Berkeley, 160 Stephens Hall #2302, Berkeley, CA 94720-2302, (510) 642-1356. E-mail [studyabroad@berkeley.edu](mailto:studyabroad@berkeley.edu) or visit [studyabroad.berkeley.edu](http://studyabroad.berkeley.edu).

### Financial Aid

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

Students may contact the Office of Financial Aid, University of California, Berkeley, 250 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 [students.berkeley.edu/finaid](http://students.berkeley.edu/finaid).

There are several scholarships restricted to students in the College of Chemistry; some are based on merit and are independent of financial need. Students may inquire about these scholarship opportunities at the College of Chemistry Undergraduate Advising Office.

### Disabled Students' Program

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

### Alumni, Development, and Public Affairs

All graduates are invited to join the College of Chemistry Alumni Association. No dues are charged. Students also can become involved with Alumni Association activities while they are still enrolled. The Alumni Association provides online mentoring to interested students.

All alumni receive *Catalyst*, a semiannual publication written specifically for them. Current news stories are posted online at [chemistry.berkeley.edu](http://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 90 percent of the college's budget that does not come from the state of California. Private funds have been used, among other things, for undergraduate scholarships, graduate fellowships, the library, facilities, and research.



## Undergraduate Programs

University of California, Berkeley  
College of Chemistry  
Undergraduate Advising Office  
4th Floor Latimer Hall #1460  
Berkeley, CA 94720-1460  
(510) 642-7919  
chemistry.berkeley.edu

Undergraduates have a choice of the following degree programs:

**The Bachelor of Science Degree in Chemical Engineering**, intended as preparation for a career in chemical engineering and related disciplines, permits a broad range of interdisciplinary concentrations in such areas as biotechnology, chemical processing, applied physical science, environmental technology, and materials science and technology.

**The Bachelor of Science Degree in Chemistry** is intended for students who are primarily interested in careers as professional chemists or wish a thorough grounding in chemistry in preparation for professional or graduate school. In addition, there is a Materials Chemistry concentration that is intended for students interested in the application of basic chemical principles to the discovery, design, and characterization of materials.

**The Bachelor of Science Degree in Chemical Biology** is intended for students who are interested in careers as professional chemists, or in the biological sciences including the biomedical, biotechnology, and pharmaceutical industries. Chemical biology offers students the opportunity to understand the chemical principles of biological function. In addition to an introductory set of math and physics courses and a broad selection of chemistry courses similar to those required for the chemistry major, students pursuing the chemical biology major take courses in general and cell biology, biochemistry, biological macromolecular synthesis, and in bioinorganic chemistry. There is a strong emphasis on organic chemistry, quantitative thermodynamics, and kinetics to understand the logic of biological systems.

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

Also, **two B.S. degree joint major programs** (Chemical Engineering and Materials Science and Engineering, and Chemical Engineering and Nuclear Engineering) are offered through the College of Chemistry.

## Admission

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

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

### Admission as a Freshman

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

### 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 coursework by the end of the spring term before transfer to Berkeley. Students are encouraged to investigate the University-preparatory programs offered by many community colleges throughout California. Up to 70 UC-transferable semester units may be transferred from a community college.

In addition to satisfying UC minimum eligibility requirements, College of Chemistry transfer applicants are expected to complete specific chemistry, math, physics, and reading and composition courses. Detailed information about these minimum requirements for admission is available at [http://chemistry.berkeley.edu/student\\_info/undergrad\\_info/prospective\\_undergrad/admission/transfer\\_students.php](http://chemistry.berkeley.edu/student_info/undergrad_info/prospective_undergrad/admission/transfer_students.php).

## Degree Requirements

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

### Entry-Level Writing

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

### American History and Institutions

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

UC Berkeley courses that fulfill the AH&I requirements are History 7A, 7B, 130B, 131A, 131B, or 138 for the American History requirement and Political Science 1, 1AC, or 108A for the American Institutions requirement. More information is available at [registrar.berkeley.edu/Default.aspx?PageID=ahi.html](http://registrar.berkeley.edu/Default.aspx?PageID=ahi.html).

### American Cultures

The American Cultures (AC) Breadth requirement is a Berkeley campus requirement. The AC requirement was established in 1989 to introduce students to the diverse cultures of the United States through a comparative framework. Students satisfy the requirement by passing, with a grade no lower than C- or P, an AC course. Courses are offered in more than 50 departments in many different disciplines at both the lower and upper division levels. For current AC course offerings, students may search the online *Schedule of Classes* ([schedule.berkeley.edu](http://schedule.berkeley.edu)) by typing American Cultures in the "Additional Information" box. Students can also access a list of AC

8 courses, as well as answers to frequently asked questions, on the AC web site at [amercult.berkeley.edu](http://amercult.berkeley.edu). Students who have questions about satisfying the AC requirement should contact their staff advisers. American Cultures courses also count toward the Breadth requirement.

### Senior Residence

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

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

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

### Minimum Total Units

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

### Grades

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

## Scholarship Requirements

### Academic Probation

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

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

Students on academic probation are placed under the supervision of the Undergraduate Dean. 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 and biomolecular engineering or chemistry course for which a grade of C- or higher is required must repeat the course *at Berkeley*.

Students in the College of Chemistry must achieve:

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

Chemistry or chemical biology students must also achieve:

- a grade of C- or higher in Chemistry 120A and 120B if taken before 125 or C182; and
- at least a 2.0 GPA in all upper division courses taken at the University to satisfy major requirements.

Chemical engineering students must also achieve:

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

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

### Minimum Progress

For undergraduates, normal progress toward a degree requires 30 units of successfully completed coursework each year. The continued enrollment of a student who fails to achieve minimum academic progress shall be subject to the approval of the Undergraduate Dean. 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 class schedule must contain at least 13 units in any term, unless otherwise authorized by the staff adviser or the Undergraduate Dean.



## Academic Policies

### Academic Advising and Approval of Planned Class Schedules

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

Undergraduate staff advisers are assigned to assist students in choosing courses, to approve students' petitions, and to advise students on other academic matters.

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 guide.

### Class Schedule Requirements

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

Chemical engineering freshmen and students majoring in Chemistry are required to enroll in a minimum of one chemistry course each semester. Students majoring in Chemical Engineering other than freshmen are required to enroll in a minimum of one chemical and biomolecular 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 also expected to complete the Reading and Composition requirement as soon as possible, so they have a foundation for courses that require writing skills. Students must complete a first-level reading and composition course (e.g., English R1A) by the end of their freshman year and, for Chemical Biology and Chemistry majors only, a second-level course (e.g., Rhetoric R1B) by the end of their sophomore year.

### Changes to Planned Class Schedules

The deadline for adding courses without a fee is the third Friday after instruction begins, and the deadline for adding courses with a fee is the fifth Friday after instruction begins. The deadline for dropping courses without a fee and for dropping early-drop-deadline courses is the second Friday after instruction begins. The deadline for dropping courses with a fee is the fifth Friday after instruction begins. The deadline for changing grading option is the tenth Friday after instruction begins. After the fifth Friday of classes, proposed grading



option changes must be submitted to the student's staff adviser on a petition to change class schedule.

Visit [chemistry.berkeley.edu/student\\_info/undergrad\\_info](http://chemistry.berkeley.edu/student_info/undergrad_info) for specific deadlines each semester.

After the above deadlines the Undergraduate Dean's approval is required for class schedule changes. Late class schedule changes will be granted only under rare and exceptional circumstances. All courses for which a drop is *processed after the fifth Friday of instruction* will appear on the student's official transcript permanently. Waiver of the transcript notation is rarely granted.

### Passed/Not Passed Courses

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

- for chemistry or chemical biology majors, Foreign Language requirement and 15-unit Breadth requirement except for Reading and Composition; and
- for chemical engineering majors, 19-unit Breadth requirement except for Reading and 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 a student's GPA.

Students on academic probation (below a C average, either overall or for the previous semester) are not allowed to take courses on

a *passed/not passed* basis with the exception of recreational physical education courses and courses offered only on a *passed/not passed* basis.

### Limit on Semesters

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

### Additional Transfer Credit

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

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

## 10 Withdrawal and Readmission

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

*Note:* Fee refunds are based on the date on which the adviser processes the withdrawal, not when the student stopped attending classes. Consult the online *Schedule of Classes* ([schedule.berkeley.edu](http://schedule.berkeley.edu)) for the fee refund schedule.

After withdrawing or being absent for one or more semesters, the student may apply for readmission by submitting an Application for Readmission to the staff adviser.

Readmission is not guaranteed and is based upon the student’s academic record at the time of withdrawal, upon any coursework taken during the absence from Berkeley, and upon the resolution of the problems that contributed to the withdrawal. If the student attended other institutions during the absence, the student must present official transcripts from each institution before readmission will be considered.

### Change of College

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

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

## Double Majors and Simultaneous Degrees

Students who wish to pursue double majors or simultaneous degrees:

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

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

Double majors in Chemistry and Chemical Biology are not permitted.

### Minors

For students in the College of Chemistry who plan to pursue a minor, at least four courses taken for the minor must not be included in the student’s major program.

## Academic Opportunities

### Undergraduate Research

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

In the Department of Chemistry students may engage in research under the direction of a faculty member. Such research may include any area of study represented by the faculty of the department.

Chemical engineering students may engage in research under the direction of a faculty member. Such research may involve independent study of selected topics and readings, as well as experimental, computation, or analytical work within the context of funded research. Research fields currently under investigation include biomolecular engineering and synthetic biology; energy storage and generation; theory, multiscale modeling or computation; micro- and nano-systems technologies; catalysis; polymers and polymer physics; and many more.

## Honors at Graduation

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

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

## College of Chemistry Scholars Program

### Recruitment and Outreach

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

### Retention

The College of Chemistry Scholars Program Retention component, in conjunction with the Recruitment and Outreach component, is designed to increase the number of students from underrepresented groups at Berkeley, to improve retention rates of these students, and to prepare them for professional careers and graduate school in science fields. Toward this end, the college offers intensive workshop courses to supplement Chemistry 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.



WALKER HALL

FRANCIS  
NEW COLLEGE  
HARRIS, RICHIE



## Department of Chemical and Biomolecular Engineering

### Chemical Engineering as a Profession

Chemical engineers contribute to a broad spectrum of technical activity reaching into practically every aspect of advanced technology. This breadth of activity is illustrated by a vast range of representative endeavors: renewable energy from biomass; man-made polymers and smart materials; new liquid and gaseous fuels from coal; drug discovery and manufacture; engineering new metabolic pathways in cells; unique chemicals from enzymatic reactions; thin-film processes for electronic devices; new catalysts for energy needs; removal of pollutants from air and water; solar energy conversion; new battery and fuel-cell systems — and countless others.

The chemical engineer's interest in these fields focuses on the invention and development of materials and processes useful to society. Historically, chemical engineers have 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 engineering 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 people in diverse technical and nontechnical areas. In some organizations, an engineer may follow a project from its laboratory developmental

stages through pilot plant evaluation, commercial plant design, plant startup, and plant operations.

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

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

### The Department of Chemical and Biomolecular Engineering (CBE)

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

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

The department is richly endowed with human and material resources to accomplish its educational objectives. Twenty-three full-time faculty members with expertise spanning nearly every major area of the field conduct courses from the sophomore level through the graduate level. All are actively engaged in research. A number of special lecturers add further breadth. Laboratories abound; for undergraduates, laboratory

courses are provided in general chemical engineering and process control (required of all students), applied kinetics, polymers, and biochemical engineering. The research laboratories are equipped for biochemical engineering, bioengineering, and biomedical engineering; phase equilibria; quantum and statistical mechanics; electrochemical engineering; catalysis and reaction engineering; rheology; polymer chemistry and physics; surface and colloid science; MEMS; materials chemistry, engineering, and synthesis; and plasma processing.

**The Chemical Engineering Undergraduate Curriculum.** The mission of the Department of Chemical and Biomolecular 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, enabling new technologies that 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 provide an educational foundation for writing clearly and persuasively, for reading critically and evaluating evidence effectively, and for understanding humanity in historical and social contexts.

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

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

- understand the fundamental mathematics and sciences that provide the foundation for engineering applications and technological innovation;
- apply scientific and engineering principles to analyze, design, and synthesize chemical and physical systems of importance to society;
- are intellectual leaders, capable of functioning creatively in an independent work environment and as a member of a team;
- use appropriate analytical, numerical, and experimental tools to investigate chemical and physical systems;
- integrate modern information technology and computational and engineering tools into engineering practice;

- communicate effectively by oral, written, and graphical means;
- are both competent and confident in interpreting the results of engineering investigations;
- appreciate the importance of, and opportunities for, lifelong learning;
- recognize the broad social context, both historical and contemporary, within which engineering is practiced; and
- understand the ethical, professional, and citizenship responsibilities of engineering practice.

## Undergraduate Programs

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

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

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

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

## Lower Division Program

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

### 19-Unit Breadth Requirement

• **Reading and Composition.** The student must demonstrate reasonable proficiency in English composition by satisfactory completion of one of the courses listed in this guide under the “College of Chemistry Breadth Requirement Course List: Group I (Reading and Composition).” This course must be taken on a letter-graded basis and should be completed by the end of freshman year. 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 Advising Office for verification of course acceptance. After admission to Berkeley, credit for English at another institution will not be granted if the Entry-Level Writing requirement has not yet been satisfied.

• **Additional Breadth and Breadth Series.** Students must complete additional courses in humanities, social sciences, or composition. Refer to the “College of Chemistry Breadth Requirement Course List” in the “General Information” section of this publication. As part of the 19 units, students are required to complete two courses (Breadth Series), 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 Breadth Series requirement. Students may continue fulfilling the 19-unit Breadth requirement in the junior or senior year. *Note:* Courses that satisfy the UC requirements of American History and Institutions or the Berkeley campus requirement of American Cultures also count toward the 19-unit Breadth requirement.

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

**CBE.** 40, 140, 141, 150A. All freshmen are required to complete 40, an introduction to basic principles of chemical process design, during their first semester. Students *must* complete 140 with a grade of C- or better before enrolling in *any other course* in CBE. A grade of C- or better in 150A is required before any additional course in the 150 series may be taken.

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

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

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

**Biology.** 1A (lecture only). (*Note:* Biotechnology-concentration students are required to take Molecular and Cell Biology 102 or Chemistry 135 in place of Biology 1A.)

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

### Suggested Lower Division Program for Chemical Engineering

Freshman Year	Units	
	Fall	Spring
Chemistry 4A-4B	4	4
CBE 40	2	-
Mathematics 1A-1B	4	4
Physics 7A	-	4
Engineering 7	-	4
English Composition	4	-
<sup>1</sup> Breadth Elective	3	-
<sup>3</sup> Total	17	16
Sophomore Year		
Chemistry 112A	5	-
CBE 140, 141	4	4
CBE 150A	-	4
Mathematics 53-54	4	4
Physics 7B	4	-
Biology 1A	-	3
<b>Total</b>	<b>17</b>	<b>15</b>

<sup>1</sup>May be taken on *passed/not passed* basis.

<sup>2</sup>Biotechnology-concentration students who do not have a background substantially equivalent to Biology 1A may want to take Biology 1A as a prerequisite to Molecular and Cell Biology 102 or Chemistry 135.

<sup>3</sup>For the first semester, students may consider taking one fewer course.

## Representative Undergraduate Chemical Engineering Program

Freshman		Sophomore		Junior		Senior			
Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring		
4A General/Quant Analysis <b>Chemistry</b>		4B Organic 112A		Biology 1A		Engineering 45	Chemistry 120A or Physics 137A	Science Elective	Engineering Elective
1A <b>Mathematics</b>				185 Technical Comm		Electrical Engineering 100	CBE Elective	Engineering Elective	
Reading and Composition	7A <b>Physics</b>		7B		141 Thermo- dynamics		142 Kinetics		Breadth Electives
Breadth Elective	Engineering 7	140 Process Analysis		150A Transport Processes		150B		<b>CBE</b>	
						154* Lab		162* Process Control	
								160* Design	
CBE 40									

\*154, 160, and 162 may be taken in any order.

### Upper Division Program

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

**Chemistry.** 120A, or Physics 137A.

**CBE.** 142, 150B, 154, 160, 162, 185.

**Engineering.** 45.

**Electrical Engineering.** 100.

### Additional Electives and Concentrations

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

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

### Open Elective Program

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

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

### Concentrations

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

#### Biotechnology

- Chemistry 112B or Molecular and Cell Biology C112
- CBE 170A, 170B, and C170L

<sup>1</sup>*Note:* Biotechnology-concentration students are required to take Molecular and Cell Biology 102 or Chemistry 135 in place of Biology 1A.

### Chemical Processing

- Chemistry 104A or 112B
- 6 units of CBE electives chosen from the following: 170A, 170B, C170L, 171, 176, C178, 179, H194 (up to 3 units)
- 3 units of engineering selected from the following: Civil and Environmental Engineering C30, 111, 114, 173; Materials Science and Engineering 111, 112, 113, C118, 120, 121, 122, 123; Mechanical Engineering 140, 151

### Environmental Technology

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

### Materials Science and Technology

- one of Chemistry 104A, 108, or 112B
- 3 units of CBE elective selected from the following: 176, C178, 179
- 6 units chosen from the following: Civil and Environmental Engineering C30; Electrical Engineering 130, 143; Materials Science and Engineering 102, 103, 111, 112, 120, 121, 122, 123, 125; Mechanical Engineering 122, 127

### Applied Physical Science

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

<sup>1</sup>Biotechnology-concentration students who do not have a background substantially equivalent to Biology 1A may want to take Biology 1A as a prerequisite to Molecular and Cell Biology 102 or Chemistry 135.

<sup>2</sup>Students may take Mechanical Engineering 122 without the prerequisites of Civil and Environmental Engineering 130N and Mechanical Engineering 108.

## Representative Chemical Engineering Program for Transfer Students

Junior		Senior		
Fall	Spring	Fall	Spring	Fall
Chemistry 112A	Biology 1A	Chemistry 120A or Physics 137A	Science Elective	Engineering Elective
Engineering 45	Electrical Engineering 100	185 Technical Comm	CBE Elective	Engineering Elective
Engineering 7	150A Transport Processes		Breadth Elective	160* Design
140 Process Analysis	141 Thermo-dynamics	150B Kinetics	154* Lab	162* Process Control

\*154, 160, and 162 may be taken in any order.

## Joint Major Programs

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

### General Requirements

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

### Chemical Engineering and Materials Science and Engineering

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

### Chemical Engineering and Nuclear Engineering

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

## Representative Chemical Engineering Program for Transfer Students

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



<b>Joint Major Program in Chemical Engineering and Materials Science and Engineering</b>			<b>127-129 Units</b>	
<i>Freshman Year</i>	<i>Fall</i>	<i>Spring</i>		
Math 1A, 1B, Calculus	4	4		
Chemistry 4A, 4B (or 1A, 1AL, 1B), General Chemistry	4	4		
Physics 7A, Physics for Scientists and Engineers	-	4		
Eng 7, Introduction to Computer Programming for Scientists and Engineers	-	4		
<sup>1</sup> English R1A or Equivalent	4	-		
<sup>1</sup> Breadth Elective	3	-		
<b>Total</b>	<b>15</b>	<b>16</b>		
<i>Sophomore Year</i>				
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	-		
CBE 140, Introduction to Chemical Process Analysis	4	-		
CBE 141, Chemical Engineering Thermodynamics	-	4		
CBE 150A, Transport Processes	-	4		
<b>Total</b>	<b>17</b>	<b>16</b>		
<i>Junior Year</i>				
EE 100, Electronic Techniques for Engineering	-	4		
Eng 45, Properties of Materials	3	-		
<sup>2</sup> Mat Sci 102, Bonding, Crystallography, and Crystal Defects	3	-		
Mat Sci 103, Phase Transformations and Kinetics	-	3		
<sup>3</sup> Mat Sci Elective	-	3		
Chemistry 120A, Physical Chemistry or Physics 137A, Quantum Mechanics	3-4	-		
CBE 142, Chemical Kinetics and Reaction Engineering	4	-		
CBE 150B, Transport and Separation Processes	4	-		
CBE 185, Technical Communication	-	3		
<sup>1</sup> Breadth Elective	-	3		
<b>Total</b>	<b>17-18</b>	<b>16</b>		
<i>Senior Year</i>				
<sup>3</sup> Mat Sci Elective	3-4	-		
Mat Sci 120, Materials Production	3	-		
Mat Sci 130, Experimental Materials Science	3	-		
CBE 154, Chemical Engineering Laboratory	4	-		
CBE 160, Chemical Process Design	-	4		
CBE 162, Dynamics and Control of Chemical Processes	-	4		
<sup>1</sup> Breadth Electives	3	6		
<b>Total</b>	<b>16-17</b>	<b>14</b>		

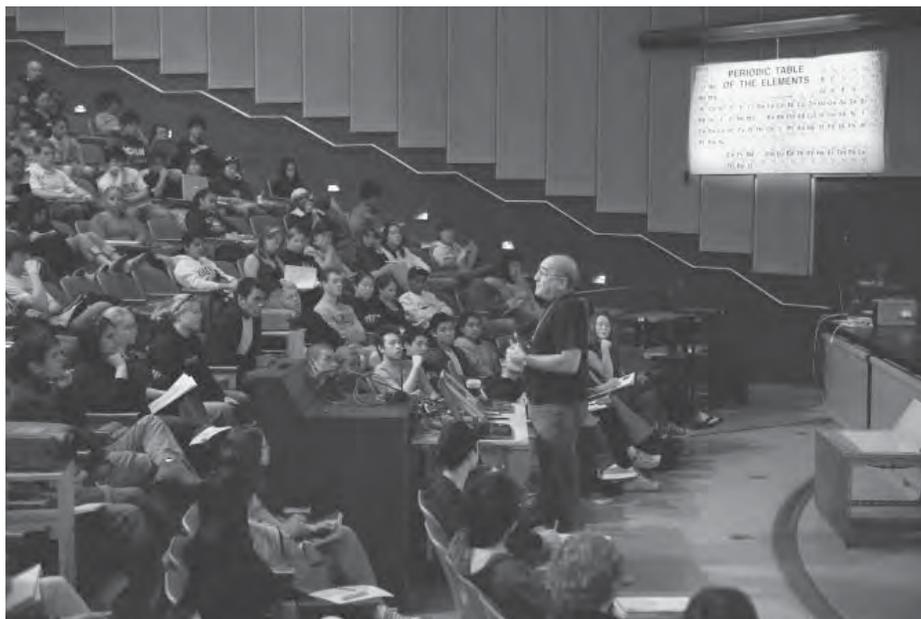
<sup>1</sup>Breadth Electives must include 19 units of humanities (including English composition) and social sciences which satisfy the requirement as specified on page 13 of this guide.

<sup>2</sup>Permission from the Mat Sci 102 instructor is required to take Eng 45 concurrently.

<sup>3</sup>Mat Sci Electives must include one course from Mat Sci 104, 111, 112, 113, 117, C118, or 151; and one course from Mat Sci 121, 122, 123, or 125.

<b>Joint Major Program in Chemical Engineering and Nuclear Engineering</b>			<b>126-128 Units</b>	
<i>Freshman Year</i>	<i>Fall</i>	<i>Spring</i>		
Math 1A, 1B, Calculus	4	4		
Chemistry 4A, 4B (or 1A, 1AL, 1B), General Chemistry	4	4		
Physics 7A, Physics for Scientists and Engineers	-	4		
Eng 7, Introduction to Computer Programming for Scientists and Engineers	-	4		
<sup>1</sup> English R1A or Equivalent	4	-		
<sup>1</sup> Breadth Elective	3	-		
<b>Total</b>	<b>15</b>	<b>16</b>		
<i>Sophomore Year</i>				
Math 53, 54, Multivariable Calculus; Linear Algebra and Differential Equations	4	4		
Physics 7B, 7C, Physics for Scientists and Engineers	4	4		
CBE 140, Introduction to Chemical Process Analysis	4	-		
CBE 141, Chemical Engineering Thermodynamics	-	4		
CBE 150A, Transport Processes	-	4		
EE 100, Electronic Techniques for Engineering	4	-		
<b>Total</b>	<b>16</b>	<b>16</b>		
<i>Junior Year</i>				
Eng 45, Properties of Materials	3	-		
Eng 117, Methods of Engineering Analysis	3	-		
Nuc Eng 101, Nuclear Reactions and Radiation	4	-		
Nuc Eng 104, Radiation Detection and Nuclear Instrumentation Lab	-	4		
Nuc Eng 150, Nuclear Reactor Theory	-	3		
<sup>4</sup> Nuc Eng Elective	-	3		
CBE 142, Chemical Kinetics and Reaction Engineering	4	-		
CBE 150B, Transport and Separation Processes	4	-		
CBE 185, Technical Communication	-	3		
<sup>1</sup> Breadth Elective	-	3		
<b>Total</b>	<b>18</b>	<b>16</b>		
<i>Senior Year</i>				
<sup>4</sup> Nuc Eng Electives	6	-		
Chemistry 120A, Physical Chemistry or Physics 137A, Quantum Mechanics	3-4	-		
CBE 154, Chemical Engineering Laboratory	4	-		
CBE 160, Chemical Process Design or Nuc Eng 170A, Nuclear Design	-	3-4		
CBE 162, Dynamics and Control of Chemical Processes	-	4		
<sup>1</sup> Breadth Electives	3	6		
<b>Total</b>	<b>16-17</b>	<b>13-14</b>		

<sup>4</sup>Nuc Eng Electives: Students select nine units of upper division Nuc Eng courses, including at least two courses selected from Nuc Eng 120, 124, or 161.



**Molecular and Cell Biology** 32, 41, 50, C61, C62, 64, C100A, 100B, 102, C103, 104, 111, C112, 113, C114, 115, C116, 130A, 132, 133L, 135A, 135E, 136, 140, 140L, 141, 143, C148, 150, C160, 160L, 163, 166, 167

**Nutritional Science and Toxicology** 10, 11, 106, 107, 108A, 110, C112, C119, 120, 150, 160, 171

**Physics** 7C, C21, 105, 110A, 110B, 112, 129, 130, 132, 137B, 138, 141A, 177

**Plant and Microbial Biology** 10, 40, C102, C102L, C103, C107, C107L, 110, 110L, C112, C114, C116, 120, 120L, 122, 135, C148, 150, 160, 170, 180

**Psychology** 110, 111, C112, C113, 114, 115A, C115B, C116, 117, 119, 122, C126, C127, C129

**Public Health** C102, 162A, C170B, 172, C172

**Undergraduate and Interdisciplinary Studies** C12

## Suggested Engineering Electives

The engineering elective courses required for the open elective program or the applied physical science concentration must be selected from the list below, or from among the engineering courses listed under the concentrations (see page 14).

**Bioengineering** 100, 104, C105B, 110, 111, 112, C112, C117, 121, C125, 132, C136L, 143, C144, C144L, 147, 150, 151, 163, C165, C181

**CBE** 170A, 170B, C170L, 171, 176, C178, 179, 180, H194, C195A, 196

**Chemistry** C138

**Civil and Environmental Engineering** 103, 105, 114, 120, 130N, 131, C133, 175, 176, 180, 186, 193

**Computer Science** C149

**Electrical Engineering** 105, C125, 130, 134, 143, C145B, C145O, 147, C149

**Engineering** 117, 120

**Industrial Engineering and Operations Research** 160, 162

**Materials Science and Engineering** 112, 113, 120, 121, 122, 123, 136, 140, 151

**Mechanical Engineering** 102A, 102B, 104, C105B, 106, 107, 108, 109, 110, C115, C117, 119, 122, 127, 131, 135, 140, 142, 146, 151, 166, 171, C177L, C180, 185

**Nuclear Engineering** 101, 124

**Plant and Microbial Biology** C124, C144, C144L

## Chemical Engineering Minor

A minor in chemical engineering will be awarded to students who have successfully completed five upper division CBE courses as follows: 140, 141, and 150A plus any two courses selected from 142, 150B, 162, 170A, 170B, 171, 176, C178, 179, 180, 185, or C195A. 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 GPA in the courses taken for the minor for both of the following: (1) courses taken at Berkeley and (2) courses taken at another institution and accepted by the College of Chemistry as equivalent to courses at Berkeley. For the minor to be awarded, the student must submit a notification of completion of the minor to the College of Chemistry Undergraduate Advising Office.

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

## Suggested Physical and Biological Science Courses

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

*Note:* Advanced Placement, Advanced Level, and International Baccalaureate credit cannot be used to satisfy the science elective for the open elective program.

**Anthropology** 1, C100, C103, 107, C131, 132, 134, 135

**Astronomy** 3, 7A, 7B, 10, C10, C12, C162

**Biology** 1B

**Chemistry** 103, 104A, 104B, 105, 108, 112B, 113, 114, 115, 120B, 122, 125, C130, 135, 143, 146, C150, C182, C191, 192, H194, 196

**Civil and Environmental Engineering** C106, C116

**Cognitive Science** C102, C110, C126, C127

**Computer Science** C182

**Earth and Planetary Science** 3, 8, C12, 20, C20, 50, 80, 100A, 103, 105, 108, 117, C129, 130, C141, C146, C162, C171, C180, 181, C182, 185

**Energy and Resources Group** 102

**English** C77

**Environmental Science, Policy, and Management** 2, 4, C10, C11, C12, 40, 42, 44, 100, 102A, 102B, 102C, C103, 106, C107, 108A, 108B, 109, 110, 112, 113, 114, 115B, 117, 118, 119, 120, C128, C129, C130, 131, 134, 137, C138, 140, 142, 144, 145, 146, 148, C149, 152, 172, 174, C180, 181, 185, 186, 187

**Environmental Sciences** 10, 125

**Geography** 1, 35, 40, C136, 137, 140A, C141, 143, 144, C145, 148, 171

**Integrative Biology** 31, 32, 41, C82, C101, C101L, 102, 102LF, 103, 103LF, 104, 104LF, 106, 106A, C107, C107L, 117, 117L, 118, 123A, 123AL, 131, 135, 137, C139, C142L, C143A, C143B, 144, 148, C149, 151, 152, 153, 154, 154L, 155, C156, 157L, 158LF, 159, 161, 162, 164, 165, 168, 168L, 169, 174, 174LF, 183, 183L, 184, 184L, C185L, 187

**Letters and Science** C30U, C30V, C30W, C70T, C70U, C70W, C70Y

**Linguistics** C109

**Materials Science and Engineering** C150

## Faculty Research Interests

Chemical engineering is a very broad discipline. Even though the department is titled "Chemical and Biomolecular Engineering," faculty research is not necessarily parsed into these two separate domains. Our research activities can be artificially categorized by the major themes of undergraduate education (transport, thermodynamics, kinetics, design), or by the compelling societal needs of our time (education, energy, environment, health, world prosperity). The research interests of faculty members in the department balance fundamental and applied research areas, while specific topics range from experimental to theoretical. Faculty in chemical engineering enjoy considerable opportunities for research as a consequence of our strong relationship with the Lawrence Berkeley National Laboratory (LBNL), a DOE-funded national laboratory located adjacent to the Berkeley campus. Some specific examples of faculty research are given below.

### Biomolecular Engineering and Synthetic Biology

Biomolecular engineering enterprises within the CBE department are driven in part by the increasingly important role this field has in the world economy. Chemical engineers with expertise in biotechnology are key to the transformation of basic research results into manufacturing processes and/or commercial products. For example, microbial production of foodstuffs, specialty chemicals, pharmaceuticals, and biofuels are industrial processes that require chemical engineering development and design approaches, but practitioners must possess a strong understanding of biochemistry and molecular biology. One powerful tool deployed by our faculty is "synthetic biology," which includes the use of genetic tools to aid in the manipulation of microbial metabolism and biosynthetic pathways. Gene therapy and stem cell biology are further examples of tools employed by our faculty that have particular application to regenerative medicine and tissue engineering. The engineering design of biocatalysts and nanobioreactors for use in biotechnology, including in non-aqueous solvents and other harsh environments, is also accomplished in our research programs. Analysis of protein structure and dynamics, both experimentally and computationally, complements our design studies and often involves the development of new analytical platforms and methods, as well as new computer algorithms for capturing protein dynamics and function. Finally, experimental and computational analysis of transport phenomena in biomedical devices such as contact lenses and microfluidic systems provides opportunities to connect our research to patient care and medical diagnosis.

## Energy

UC Berkeley co-hosts several extraordinary centers for energy research: the Energy Biosciences Institute (EBI), funded by BP, whose mission is to harness the potential of bioenergy; the Joint BioEnergy Institute (JBEI), a DOE-funded partnership with the primary scientific mission of advancing the development of the next generation of biofuels; the Batteries for Advanced Transportation Technologies (BATT) program within LBNL, whose mission is to develop high-performance rechargeable batteries for electric and hybrid-electric vehicles; and a DOE Energy Frontier Research Center for Gas Separations Relevant to Clean Energy Technologies, which aims to remove carbon dioxide from flue gases emanating from power plants, as well as numerous other programs focused on fuel cells, photovoltaics, and other forms of renewable energy. CBE faculty are also leaders within the Joint Center for Artificial Photosynthesis (JCAP), the nation's largest research program dedicated to the development of an artificial solar-fuel generation technology. The research scope of these centers spans synthetic biology and metabolic engineering, surface science, catalysis and reaction engineering, electrochemical engineering, computation and modeling, inorganic chemistry, polymer science, and materials engineering.

### Theory, Multiscale Modeling, and Computer Simulation

Chemical engineering faculty are engaged in the development of computational methodologies that can be used to analyze and design systems that involve multiple temporal and spatial domains. For example, such methods are applied to the use of emerging concepts in statistical physics and chemistry towards the study of molecules confined to small spaces, surfactant and biomolecule self-assembly, vapor-liquid equilibrium, and critical phenomena. These methods are particularly important in biomolecular engineering where applications of computational methods include the analysis of allosteric modulation of membrane receptors, mechanical responses of biomolecules, effects of hydration on protein conformation and protein-protein interactions, and protein stability at interfaces. Finally, the gas electric discharge is a powerful tool for generating plasmas for broad applications ranging from modifying materials to improving public health. In these systems the key problems addressed by computation and modeling are the complex coupling between chemically reactive neutral gas; electrons and ions; photons that make up the plasma, and their interaction bounding surfaces.

### Micro- and Nanosystems and Technologies

Chemical and materials science and engineering principles play an important role in sustaining information systems as elements

of world economic prosperity and productivity. The Berkeley faculty focus their research in this field to chemical and physical phenomena associated with new micro- and nanostructured devices and their sustainable manufacture. Examples include tailored nanostructures for electromechanical systems (MEMS or NEMS), preparation of new materials for electronics applications, such as silicon carbide, graphene, and self assembly of polymeric materials, and fundamental studies of nanostructures for spintronic and other computational devices. Important in these faculty research efforts are fundamental studies of processing science for manufacture, including plasma etching and deposition of materials, control of molecular ordering and assembly, and surface modification for device stability and protection.

## Catalysis

The kinetics of chemical reactions occurring at the surface of solids is an area of important industrial application, including preparation of fuels, chemicals, and specialty materials. The CBE faculty seek a molecular-level understanding of surface reactions as ascertained by the use of spectroscopy (NMR, ESR, infrared and RAMAN, optical, and X-ray) 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. Molecular control of material structure for adsorption, catalysis, and sensing are also important goals for our faculty research.

## Polymers and Polymer Physics

Structured polymer materials are synthesized by our faculty for a variety of scientific reasons and technological applications. The nanoscale self-assembly of block copolymers, for example, is characterized by a delicate balance of thermodynamic and kinetic forces that demonstrate the subtle science of macromolecular enthalpic and entropic processes. Control of polymer self-assembly, if achieved, leads to highly desirable polymer properties, including tunable transport of electrons, holes, ions, water, oxygen, and alcohols. These are some of the properties that our faculty seek to exploit. For example, block copolymers are designed by our faculty for their mechanical properties for use in electroactive devices such as lithium ion batteries. Complementing the synthetic efforts are a host of (developed or emerging) optical, electron, and scanning probe microscopies, as well as X-ray and neutron techniques and rheological, spectroscopic, light-scattering, dielectric, and nonlinear optical methods for polymer characterization.

## Courses

### 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.

**40. Introduction to Chemical Engineering Design. (2)** One hour of lecture and one and one-half hours of discussion per week. *Prerequisite: Math 1A, which may be taken concurrently.* Design and analysis of processes involving chemical change. Strategies for design, such as creative thinking and (re)definition of the design goal. Methods for analyzing designs, such as mathematical modeling, empirical analysis by graphics, and dynamic scaling by dimensional analysis. Design choices in light of process efficiency, product quality, economics, safety, and environmental issues. (F)

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

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

### Upper Division Courses

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

**141. Chemical Engineering Thermodynamics. (4)** Three hours of lecture and one hour of discussion per week. *Prerequisites: 140 with a grade of C- or higher; Engineering 7, which may be taken concurrently.* Thermodynamic behavior of pure substances and mixtures. Properties of solutions, phase equilibria. Thermodynamic cycles. Chemical equilibria for homogeneous and heterogeneous systems. (S)

**142. Chemical Kinetics and Reaction Engineering. (4)** Three hours of lecture and one hour of discussion per week. *Prerequisites: 141; 150B, which may be taken concurrently.* Analysis and prediction of rates of chemical conversion in flow and nonflow processes involving homogeneous and heterogeneous systems. (F)

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

**150B. Transport and Separation Processes. (4)** Three hours of lecture and one hour of discussion per week. *Prerequisites: 150A with a grade of C- or higher; Engineering 7.* 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. (4)** One hour of lecture and eight hours of laboratory per week. *Prerequisites: 141, 150B, 185.* 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)

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

**162. Dynamics and Control of Chemical Processes. (4)** Three hours of lecture and one hour of computer 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 process simulations. (F, S)

**170A. Biochemical Engineering. (3)** Formerly 170. Three hours of lecture per week. *Prerequisites: 150B or consent of instructor; Biology 1A.* The first of a two-semester sequence intended to introduce chemical engineers to the basic concepts of biochemical engineering. The course focuses on the use of chemical engineering skills and principles in



the analysis and design of biologically-based processes. No previous background in the biological sciences has been assumed, and no subsection of the course has been set aside to cover fundamental topics in biochemistry, molecular biology, or microbiology. Instead, such material will be introduced as necessary throughout the course. The main emphasis of the 170A-170B sequence will be on biochemical kinetics, heat and mass transfer, thermodynamics, and transport phenomena as they apply to enzyme catalysis, protein engineering, microbial growth and metabolism, fermentation and bioreactor design, product recovery, and downstream processing. (F)

**170B. Biochemical Engineering. (3)** Formerly 170. Three hours of lecture per week. *Prerequisites: 170A; Chemistry 135 or Molecular and Cell Biology 102, which may be taken concurrently.* The second of a two-semester sequence intended to introduce chemical engineers to the basic concepts of biochemical engineering. The course focuses on the use of chemical engineering skills and principles in the analysis and design of biologically-based processes. The emphasis will be on biochemical kinetics, protein engineering, cell growth and metabolism, bioreactor design, downstream processing, pharmacokinetics, drug delivery, and ethics. (S)

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

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

**176. Principles of Electrochemical**

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

**C178. Polymer Science and Technology.**

**(3)** Two hours of lecture and three hours of laboratory per week. *Prerequisite:* Junior standing. An interdisciplinary course on the synthesis, characterization, and properties of polymer materials. Emphasis on the molecular origin of properties of polymeric materials and technological applications. Topics include single molecule properties, polymer mixtures and solutions, melts, glasses, elastomers, and crystals. Experiments in polymer synthesis, characterization, and physical properties. Also listed as Chemistry C178. (F)

**179. Process Technology of Solid-State**

**Materials Devices. (3)** Three hours of lecture per week. *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)

**180. Chemical Engineering Economics. (3)**

Three hours of lecture per week. *Prerequisite:* Consent of instructor. Optimal design of chemical processes and unit operations, emphasizing the interactions between technical and economic considerations. Analysis of process risks. Chemical and biomolecular process design in the presence of uncertainties. Interest rate determinants and their effects

on chemical process feasibility and choices. Relationships between structure and behavior of firms in the chemical processing industries. Multivariable input-output analyses. (F, S)

**185. Technical Communication for Chemical**

**Engineers. (3)** Three hours of lecture per week. *Prerequisites:* 140; English R1A or equivalent; consent of instructor. Development of technical writing and oral presentation skills in formats commonly used by chemical engineers. (F, S)

**H194. Research for Advanced**

**Undergraduates. (2-4)** Individual conferences. *Prerequisites:* Minimum GPA of 3.4 overall at Berkeley and consent of instructor. Original research under direction of one of the members of the staff. May be repeated for credit. (F, S)

**195. Special Topics. (2-4)** Individual conferences.

*Prerequisite:* Consent of instructor. Lectures and/or tutorial instruction on special topics. May be repeated for credit. (F, S)

**C195A. The Berkeley Lectures on Energy:**

**Energy from Biomass. (3)** Two hours of lecture and one hour of discussion per week. *Prerequisites:* Chemistry 1B or 4B; Math 1B; Biology 1A. After an introduction to the different aspects of our global energy consumption, the course will focus on the role of biomass. The course will illustrate how the global scale of energy guides the biomass research. Emphasis will be placed on the integration of the biological aspects (crop selection, harvesting, storage and distribution, and chemical composition of biomass) with the chemical aspects to convert biomass to energy. The course aims to engage students in state-of-the-art research. Also listed as Bioengineering C181, Chemistry C138, and Plant and Microbial Biology C124. (F)

**196. Special Laboratory Study. (2-4)** Individual conferences. *Prerequisite:* Consent of instructor. Special laboratory or computation work under direction of one of the members of the staff. May be repeated for credit. (F, S)

**197. Field Study in Chemical Engineering.**

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

**198. Directed Group Study for Under-**

**graduates. (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. *Prerequisites:* 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)

**199. Supervised Independent Study and**

**Research. (1-4)** Course may be repeated for credit. One to four hours of independent study per week. Must be taken on a *passed/not passed* basis. (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.

**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. Topics covered include molecular thermodynamics of pure substances and mixtures, interfacial thermodynamics, statistical mechanics, and computer simulations. (F)

**241. Molecular Thermodynamics for Phase Equilibria in Chemical Engineering.**

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

**244. Kinetics and Reaction Engineering.**

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

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

**246. Principles of Electrochemical Engineering.**

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

**248. Applied Surface and Colloid Chemistry.**

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

**249. Biochemical Engineering.**

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

**250. Transport Processes.**

(3) Three hours of lecture per week. *Prerequisites:* 150A, 150B; Math 53 and 54, or equivalent; open to seniors with consent of the instructor. Basic differential relations of mass, momentum, and energy including creeping, laminar, and turbulent flow, boundary layers, convective-diffusion in heat and mass transfer, and simultaneous multicomponent mass and energy transport. Analytic mathematical solution of the equations of change using classical techniques including: separation of variables, similarity solutions, and Laplace and Fourier transforms. (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.

**C268. Physicochemical Hydrodynamics.**

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

**C270. Protein Engineering.**

(3) Three hours of lecture per week. *Prerequisite:* Graduate standing or consent of instructor. An in-depth study of the current methods used to design and engineer proteins. Emphasis on how strategies can be applied in the laboratory. Relevant case studies presented to illustrate method variations and applications. Intended for graduate students. (F)

**274. Biomolecular Engineering.**

(3) Three hours of lecture per week. *Prerequisite:* Graduate standing or consent of instructor. Fundamentals in biomolecular engineering. Structures, dynamics, and functions of biomolecules. Molecular tools in biotechnology. Metabolic and signaling networks in cellular engineering. Synthetic biology and biomedical engineering applications. (S)

**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.

**C295A. The Berkeley Lectures on Energy:**

**Energy from Biomass.** (3) Two hours of lecture and one hour of discussion per week. *Prerequisites:* Chemistry 1B or 4B; Math 1B; Biology 1A. After an introduction to the different aspects of our global energy consumption, the course will focus on the role of biomass. The course will illustrate how the global scale of energy guides the biomass research. Emphasis will be placed on the integration of the biological aspects (crop selection, harvesting, storage and distribution, and chemical composition of biomass) with the chemical aspects to convert biomass to energy. The course aims to engage students in state-of-the-art research. Also listed as Bioengineering C281, Chemistry C238, and Plant and Microbial Biology C224. (F)

**295B. Electrochemical, Hydrodynamic, and Interfacial Phenomena.**

(2) Two hours of lecture per week. *Prerequisite:* Open to properly qualified graduate students. Course may be repeated for credit. (F)

**295D. Development of Biopharmaceuticals.**

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

**295F. Battery Technologies: Addressing the Growing Demand for Electrical Energy Storage.**

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

**22 295K. Design of Functional Interfaces. (3)** Three hours of lecture per week. *Prerequisite: Graduate standing.* This course introduces students to the concepts and techniques involved in the design and physical characterization of advanced functional materials consisting of well-defined interfaces. Throughout the course principles of supramolecular chemistry on solid surfaces are applied to functional systems. Materials with different connectivity and structure at the active site are compared for development of understanding. Specific topics include catalysis, separations, encapsulation, and biomedicine. (F, S)

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

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

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

**295P. Introduction to New Product Development. (3)** Three hours of lecture per week. *Prerequisite: Graduate standing or consent of instructor.* This course is part of the product development initiative sponsored by the Department of Chemical and Biomolecular Engineering. It focuses on real-life practices and challenges of translating scientific discovery into commercial products. Its scope is limited

in most circumstances to situations where some knowledge of chemical engineering, chemistry, and related disciplines might prove to be particularly useful. The course primarily uses case studies of real-world new product development situations to simulate the managerial and technical challenges that will confront students in the field. The course will cover a wide range of topics including basic financial, strategic, and intellectual property concepts for products, managing risk and uncertainty, the effective new product development team, the evolving role of corporate R&D, the new venture product company, and the ethics of post-launch product management. (F)

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

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

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

**C295Z. Energy Solutions: Carbon Capture and Sequestration. (3)** Two hours of lecture and one hour of discussion per week. *Prerequisites: Chemistry 4B or 1B, Math 1B, Physics 7B, or equivalents.* After brief overview of the chemistry of carbon dioxide in the land, ocean, and atmosphere, the course will survey the capture and sequestration of CO<sub>2</sub> from anthropogenic sources. Emphasis will be placed on the integration of materials synthesis and unit operation design, including the chemistry and engineering aspects of sequestration. The course primarily addresses scientific and engineering challenges and aims to engage students in state-of-the-art research in global energy challenges. Also listed as Chemistry C236 and Earth and Planetary Science C295Z. (F)

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

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

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

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

#### *Professional Course*

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



## 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; investigation of polysaccharides that decorate the surface of cells; elucidation of the role of small molecules in cell signaling; the production,

conversion, and storage of energy; research on photosynthesis; the development of fertilizers that help produce rich harvests; and the continuing research on the creation of new materials for nanotechnology and for medical applications.

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

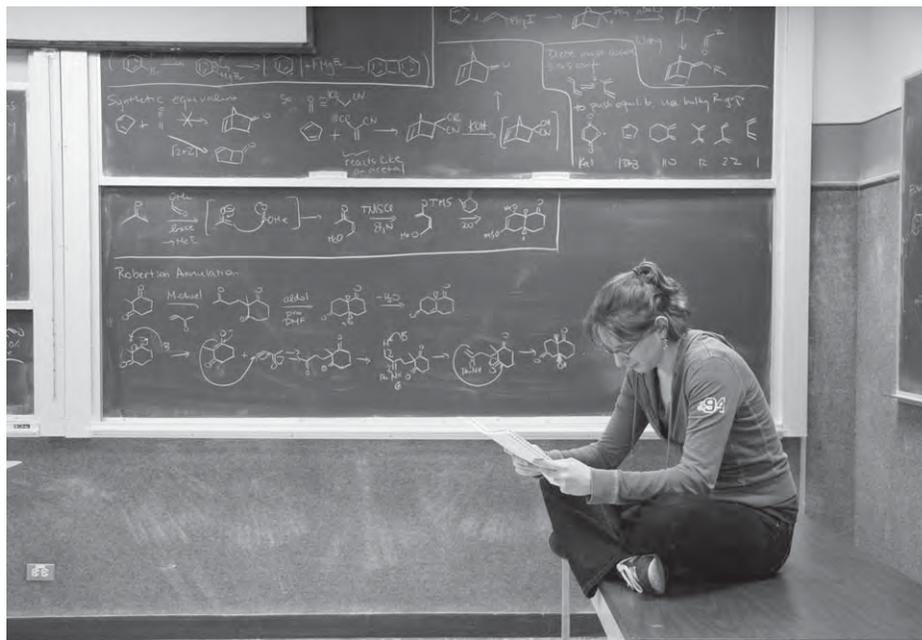
Combining the bachelor's degree in chemistry or chemical biology with a higher degree in another field can lead to many unique and rewarding careers. The B.A. in chemistry or B.S. in chemical biology is particularly useful for those who are interested in medical school and a professional career in medical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

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

### The Department of Chemistry

The chemistry department provides the opportunity for an undergraduate student to obtain a thorough fundamental knowledge of all fields of chemistry. There are lecture courses in the general areas of inorganic, organic, and physical chemistry, plus many more specialized courses including analytical, nuclear, and biophysical chemistry and chemical biology. Laboratory experience is provided in inorganic and organic synthesis, analytical methods, physical chemical measurements, spectroscopy, biochemical engineering, and chemical methods in nuclear technology. Independent and original work is stressed in the laboratories and modern equipment is available to carry out the work. The equipment and techniques available to the undergraduate student include nuclear magnetic resonance, electron paramagnetic resonance, visible, ultraviolet, and infrared 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 Molecular Graphics and Computation 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. The Chemistry and Chemical Engineering Library has an excellent collection of books, journals, and reference materials. Graduate student instructors who are themselves graduate students working toward Ph.D. degrees are further sources of scientific information and help. Faculty members are available as academic advisers and hold office hours for consultation about their courses; they are also willing to discuss chemistry, science, career opportunities, and even philosophy. The best way to take full advantage of the scientific opportunities available in the department is to join a research group. This can be done through courses for advanced undergraduates, or simply as an employee.



## Undergraduate Programs

### Choice of College and Major

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

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

The **Bachelor of Science Degree in Chemical Biology** is intended for students who are interested in careers as professional chemists, or in the biological sciences including the biomedical, biotechnology, and pharmaceutical industries. Chemical biology offers students the opportunity to understand the chemical principles of biological function. In addition to an introductory set of math and physics courses and a broad selection of chemistry courses similar to those required for the chemistry major, students pursuing the chemical biology major take courses in general and cell biology, biochemistry, biological macromolecular synthesis, and in bioinorganic chemistry. There is a strong emphasis on organic chemistry, quantitative thermodynamics, and kinetics to understand the logic of biological systems.

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

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

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

Additional information on ACS certification is available in the College of Chemistry Undergraduate Advising Office.

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

### The Bachelor of Science Degrees in Chemistry and Chemical Biology

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

- fulfilled the degree requirements and scholarship requirements as specified on pages 7 and 8 of this guide;
- satisfactorily completed a *minimum of 120 units*; and
- satisfied the specific lower division and upper division requirements for the chosen major.

#### Lower Division Requirements

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

#### 15-Unit Breadth Requirement

- **Reading and Composition.** The student must demonstrate reasonable proficiency in English composition by satisfactory completion of a first-level course (e.g., English R1A) and a second-level course (e.g., Rhetoric R1B) from the group of courses listed in this guide under the "College of Chemistry Breadth Requirement Course List: Group I (Reading and Composition)." The first-level and second-level courses need not be from the same department, but both courses must be taken on a letter-graded basis. The first-level course must be completed by the end of freshman year, and the second-level course must be completed by the end of sophomore year. 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 Advising Office for verification of course acceptance. After admission to Berkeley, credit for English at another institution will not be granted if the Entry-Level Writing requirement has not yet been satisfied.
- **Additional Breadth.** Two or more courses in the humanities and/or social sciences must be taken. These courses may not all be from the same department. Refer to the "College of Chemistry Breadth Requirement Course List: Group II (Humanities and Social Sciences)" in the "General Information" section of this publication. Students may continue fulfilling the 15-unit Breadth requirement in the junior or senior year. *Note:* Courses that satisfy the UC requirements of American History and Institutions or the Berkeley campus requirement of American Cultures also count toward the 15-unit Breadth requirement.

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

- (1) By completing in high school the third year of one foreign language with minimum grades of C-.
- (2) By completing at Berkeley the second semester of a sequence of courses in one foreign language, or the equivalent at another institution. Only foreign language courses that include reading and composition as well as conversation are accepted in satisfaction of this requirement.
- (3) By demonstrating equivalent knowledge of a foreign language through examination, including a College Entrance Examination Board (CEEB) Advanced Placement Examination with a score of 3 or higher (if taken before admission to college), an SAT II: Subject Test with a score of 590 or higher, or a proficiency examination offered by some departments at Berkeley or at another campus of the University of California.

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

**Freshman Seminar.** Chemistry 96 introduces entering freshmen to research and study in the College of Chemistry. Chemistry and chemical biology freshmen are required to take the course during their first fall semester at Berkeley. Enrollment in the course is restricted to students who recently entered the College of Chemistry.

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

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

Students who join the program after completing Chemistry 3A plus 3AL and 3B plus 3BL at Berkeley are allowed to substitute those courses for 112A and 112B. Students who join the program after completing only Chemistry 3A plus 3AL at Berkeley are recommended to take 112B.

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

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

<sup>1</sup>May be taken on *passed/not passed* basis.

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

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

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

The following program is suggested for the first two years:

Suggested Lower Division Program for Chemistry or Chemical Biology		
	Units	
Freshman Year	Fall	Spring
Chemistry 4A-4B	4	4
Chemistry 96	1	-
Mathematics 1A-1B	4	4
Physics 7A	-	4
English Composition	4	4
<sup>1</sup> Breadth Elective	3-4	-
<sup>2</sup> Total	16-17	16
Sophomore Year	Fall	Spring
Chemistry 112A-112B	5	5
Mathematics 53-54	4	4
Physics 7B	4	-
<sup>1</sup> Foreign Language for chemistry majors, or Biology 1A and 1AL for chemical biology majors	-	5
<sup>1</sup> Free Elective	3	3
<b>Total</b>	<b>16</b>	<b>17</b>

### Chemistry Major Upper Division Requirements

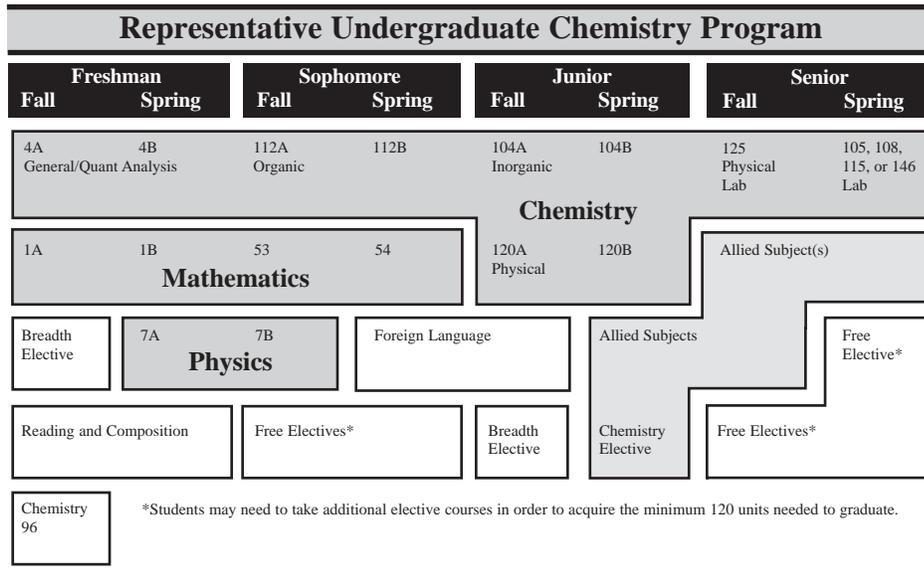
During their junior and senior years students must complete the following course requirements:

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

(*Note:* A grade of C- or higher is required in Chemistry 120A and 120B if taken before 125 or C182.)

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

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



Advanced Placement, Advanced Level, and International Baccalaureate credit cannot be applied to this requirement.

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

*Note:* If a course is used to satisfy another requirement (such as the chemistry major requirement of one of 105, 108, 115, or 146) the course cannot also be used to satisfy the Upper Division Chemistry and Allied Subjects requirement.

This program may be used to specialize in a particular area of chemistry, such as inorganic, nuclear, organic, etc. The program may also be used to develop an understanding in other fields of interest that either require a strong background in chemistry or are relevant to the chemical sciences, such as biochemistry, chemical physics, mathematics, chemical engineering, geochemistry, materials science, atmospheric chemistry, environmental science, etc.

### Materials Chemistry Concentration Upper Division Requirements

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

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

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

### Chemical Biology Major Upper Division Requirements

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

**Chemistry.** 103, C110L, 120A, 120B, 135, and *one* of the following choices: 105, 125, C170L, or C182.

(*Note:* A grade of C- or higher is required in Chemistry 120A and 120B if taken before 125 or C182.)

**Molecular and Cell Biology.** 110. Biology 1A plus 1AL and Chemistry 135 satisfy the prerequisites for Molecular and Cell Biology 110.

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

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

Advanced Placement, Advanced Level, and International Baccalaureate credit cannot be applied to this requirement.

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

*Note:* If a course is used to satisfy another requirement (such as the chemical biology major requirement of one of 105, 125, or C170L) the course cannot also be used to satisfy the Upper Division Chemistry and Allied Subjects requirement.

<sup>1</sup>May be taken on *passed/not passed* basis.

<sup>2</sup>For the first semester, students may consider taking one fewer course.

## Representative Undergraduate Chemical Biology Program

Freshman		Sophomore		Junior		Senior		
Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	
4A General/Quant Analysis		112A Organic		120A Physical		105, 125, or C170L Lab		Chemistry Elective
4B		112B		120B				
<b>Mathematics</b>				<b>Chemistry</b>				
1A		53		103 Inorganic		C110L Biochem Lab		Allied Subject(s)
1B		54		135 Chemical Biology		MCB 110		Breadth Elective
Breadth Elective	<b>Physics</b>		Biology 1A and 1AL				Free Elective*	
7A		7B		Foreign Language		Free Electives*		
Reading and Composition		Free Electives*						
Chemistry 96		*Students may need to take additional elective courses in order to acquire the minimum 120 units needed to graduate.						

**Plant and Microbial Biology**  
C103, C112, C112L, C114, C116, 120, 120L, 122, C124, 135, 135L, C144, C144L, C148, 150, 150L, 160, 160L, 170, 180

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

**Statistics**  
134, 135, C141, C143

### The Bachelor of Arts Degree in Chemistry

To graduate with a B.A. degree in Chemistry, the student must be in the College of Letters and Science and must have satisfied general University requirements, the American Cultures requirement, and College of Letters and Science requirements in addition to the major requirements. Detailed information about these requirements is available in the *General Catalog* or on the Letters and Science website: [ls.berkeley.edu](http://ls.berkeley.edu).

#### Major Requirements

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

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

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

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

**Physics.** 7A, 7B.

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

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

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

### Suggested Allied Subject Courses

**Astronomy**  
C162

**Bioengineering**  
100, 104, C105B, 111, 112, C112, 115, 116, C117, C118, C119, 121, 131, 132, C141, 143, C144, C144L, 147, 150, 151, 163, 174, C181

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

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

**Chemical and Biomolecular Engineering**  
140, 141, 142, 150A, 150B, 154, 160, 162, 170A, 170B, C170L, 171, 176, C178, 179, 180, 185, H194, 195, C195A, 196

**Chemistry**  
100 (limited to 2 units), 103, 104A, 104B, 105, 108, C110L, 113, 114, 115, 122, 125, C130, 135, C138, 143, 146, C150, C170L, C178, C182, C191, 192, H194, 195, 196

**Civil and Environmental Engineering**  
C106, 108, 111, 112, 114, 115, C116, C133

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

**Earth and Planetary Science**  
103, 105, 111, C129, 131, C162, C180, C182, 185

**Economics**  
C103

**Education**  
223B, 224A

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

**Electrical Engineering**  
100

**Energy and Resources Group**  
102

**Engineering**  
117, 128

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

**Integrative Biology**  
106A

**Materials Science and Engineering**  
102, 103, 104, 111, 112, 113, 117, C118, 120, 121, 122, 123, 125, 130, 140, 151

**Mathematics**  
C103, 104, H104, 105, 110, H110, 113, H113, 114, 115, 121A, 121B, 123, 125A, 126, 128A, 128B, 130, 135, 136, 140, 142, 170, 185, H185, 187, 189

**Mechanical Engineering**  
C105B, 107, C115, C117, 118, C124, C176, C180

**Molecular and Cell Biology**  
C100A, 102 (for chemistry majors only), C103, 104, 110, C110L, 111, C112, C112L, 113, C114, 115, C116, 118, 130A, 130L, 133L, 140, 140L, 141, 143, C148, 150, 150L, C160, 160L, 167

**Nuclear Engineering**  
101, 104, 107, 120, 124, 130, 150, 161, 162, 170A, 170B, 180

**Nutritional Science and Toxicology**  
103, 108A, 110, C112, 115, C119, 120, 150, 160, 171

**Physics**  
7C, 105, 110A, 110B, 112, 130, 137B, 138, 141A, 141B, C191

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

## 28 Chemistry Minor

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

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

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

## Faculty Research Interests

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

### Analytical Chemistry

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

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

### Biophysical Chemistry and Chemical Biology

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

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

Use of unnatural amino acids, isotopes, and sophisticated new forms of spectroscopy are also used to probe function. The roles of metals, cofactors, and even hydrogen tunneling in enzymatic reactions are being studied. Ultrafast spectroscopy can follow extremely fast photo-induced isomerizations (such as occur during vision), electron transfer processes, and electronic energy



transfer. X-ray absorption spectroscopy and XAFS are used with EPR and optical spectroscopy to unravel how energy is gathered during photosynthesis, and the role of manganese in oxygen evolution.

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

## Molecular Structure and Dynamics

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

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

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

## Organic Chemistry

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

## Nuclear Chemistry

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

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

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

## Inorganic Chemistry

Research carried out by the inorganic group covers a wide range of activities at the cutting edge of this vibrant field of chemistry. Synthetic and structural chemistry is particularly strong at Berkeley. New inorganic and organometallic complexes involving d-, f-, and p-block elements are prepared and characterized, and several groups are involved in mechanistic and reactivity studies with these compounds. Several research groups are actively studying new catalytic systems for olefin polymerization and chiral synthesis. Research on the bioinorganic chemistry of iron focuses on transport and storage of this element. Medical applications of gadolinium complexes in magnetic resonance imaging (MRI) and specific sequestering agents for the actinides are examples of metal-ion-specific complexation. Research at the interface of inorganic and physical chemistry is also represented. Synthesis coupled with static and time-resolved spectroscopies are being used to study the photochemical and photophysical properties of transition metal complexes. Exciting classes of new materials are being prepared; these include extended solids, hybrid inorganic/organic frameworks, nanostructured materials, and novel polymers. Advanced solid-state materials such as superconductors, semiconductors, and charge-transporting polymers are prepared by novel synthetic routes. Structural and property studies are carried out using a wide range of state-of-the-art techniques such as single-crystal and powder X-ray diffraction, X-ray photoelectron spectroscopy, multinuclear 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: synchrotron radiation; photoelectron spectroscopy; molecular beams; low-energy electron diffraction; X-ray diffraction; ultrafast laser spectroscopy; high-resolution and solid state NMR, ESR and optical spectroscopy; chemical synthesis; the measurement of thermodynamic and transport properties; second harmonic generation (SHG) and sum frequency generation (SFG)-surface vibrational spectroscopy; scanning tunneling microscope; atomic force microscope; and Coherent anti-Stokes Raman microscopy. Facilities are available for research over wide ranges of temperature, pressure and magnetic field, and in ultra-high vacuum. Topics under investigation include the atomic and electronic structure of metallic solids, intercalation compounds, metal and polymer surfaces and adsorbed layers; molecular studies of friction and lubrication; the nature of aqueous electrolyte interfaces; the hydration properties of biomolecules; single nanowire lasers; the relation of surface structure to the bonding and reactivity of adsorbed molecules; catalysis; phase transitions; superconductivity; relaxation dynamics; molecular motion and energy transfer in condensed phases; liquid crystals and polymers; high-temperature chemical reactions; and electrical, magnetic, and thermodynamic properties of novel materials.

## Theoretical Chemistry

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

## Courses

### Lower Division Courses

**1A. General Chemistry. (3)** Students will receive no credit for 1A after taking 4A. Three hours of lecture and one hour of discussion per week. *Prerequisite: High school chemistry recommended.* Stoichiometry of chemical reactions, quantum mechanical description of atoms, the elements and periodic table, chemical bonding, real and ideal gases, thermochemistry, introduction to thermodynamics and equilibrium, acid-base and solubility equilibria, introduction to oxidation-reduction reactions, introduction to chemical kinetics. (F, S)

**1AL. General Chemistry Laboratory. (1)** Students will receive no credit for 1AL after taking 4A. One hour of lecture and three hours of laboratory per week. *Prerequisite: 1A (may be taken concurrently).* An experimental approach to chemical sciences with emphasis on developing fundamental, reproducible laboratory technique and a goal of understanding and achieving precision and accuracy in laboratory experiments. Proper use of laboratory equipment and standard wet chemical methods are practiced. Areas of investigations include chemical equilibria, spectroscopy, nanotechnology, green chemistry, and thermochemistry. Concurrent enrollment in 1A is recommended. (F, S)

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

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

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

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

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

**4A-4B. General Chemistry and Quantitative Analysis. (4;4)** Students will receive one unit of credit for 4A after taking 1A. Students will receive three units of credit for 4A after taking 1AL. Students will receive two units of credit for 4B after taking 1B. Students will receive one unit of credit for 4B after taking 15. Three hours of lecture and four hours of laboratory per week. *Prerequisites: High school chemistry; calculus (may be taken concurrently); high school physics is recommended.* The series 4A-4B is intended for majors in engineering and physical and biological sciences. It presents the foundation principles of chemistry, including stoichiometry, ideal and real gases, acid-base and solubility equilibria, oxidation-reduction reactions, thermochemistry, entropy, nuclear chemistry and radioactivity, the atoms and elements, the periodic table, quantum theory, chemical bonding, molecular structure, chemical kinetics, and descriptive chemistry. Examples and applications will be drawn from diverse areas of special interest such as atmospheric, environmental, materials, polymer and computational chemistry and biochemistry. Laboratory emphasizes quantitative work. Equivalent to 1A-1B plus 15 as prerequisite for further courses in chemistry. 4A (F); 4B (S)

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

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

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

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

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

**96. 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 the College of Chemistry, or consent of instructor.* 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. (F)

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

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

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

#### Upper Division Courses

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

**103. Inorganic Chemistry in Living Systems. (3)** Three hours of lecture per week. *Prerequisite:* 4B or 1B. The basic principles of metal ions and coordination chemistry applied to the study of biological systems. (F)

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

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

**108. Inorganic Synthesis and Reactions. (4)** Two hours of lecture and eight hours of laboratory per week. *Prerequisites:* 4B or 15; 104B with a grade of C- or higher, or 103. 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)



**C110L. General Biochemistry and Molecular Biology Laboratory. (4)** Two hours of lecture and six to eight hours of laboratory per week. *Prerequisite:* Molecular and Cell Biology 110, which may be taken concurrently. Experimental techniques of biochemistry and molecular biology, designed to accompany the lectures in MCB 100B and MCB 110. Also listed as Molecular and Cell Biology C110L. (F, S)

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

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

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

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

**120A. Physical Chemistry. (3)** Students will receive two units of credit for 120A after taking 130B. Three hours of lecture per week. *Prerequisites:* 4B or equivalent; Physics 7B or 8B; Math 53; Math 54 (or consent of instructor). Kinetic, potential, and total energy of particles and forces between them; principles of quantum theory, including one-electron and many-electron atoms, and its applications to chemical bonding, intermolecular interactions and elementary spectroscopy. (F, S)

**120B. Physical Chemistry. (3)** Three hours of lecture per week. *Prerequisites:* 4B or equivalent; Math 53; Physics 7B or 8B; Math 54 (may be taken concurrently). Statistical mechanics, thermodynamics, equilibrium and applications to chemical systems: states of matter, solutions and solvation, chemical kinetics, molecular dynamics, and molecular transport. (F, S)

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

**125. Physical Chemistry Laboratory. (3)**

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

**C130. Biophysical Chemistry: Physical Principles and the Molecules of Life. (4)**

Three hours of lecture and one hour of discussion per week. *Prerequisites:* Math 1A, or 10A and 10B; Biology 1A and 1AL; Chemistry 3A or 112A; Chemistry 3B or 112B recommended. Thermodynamic and kinetic concepts applied to understanding the chemistry and structure of biomolecules (proteins, DNA, and RNA). Molecular distributions, reaction kinetics, enzyme kinetics. Bioenergetics, energy transduction, and motor proteins. Electrochemical potential, membranes, and ion channels. Also listed as Molecular and Cell Biology C100A. (F, S)

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

**135. Chemical Biology. (3)** Students will receive no credit for 135 after taking MCB 100B or MCB 102. Three hours of lecture per week. *Prerequisites:* 3B or 112B; Biology 1A; or consent of instructor. One-semester introduction to biochemistry, aimed toward chemistry and chemical biology majors. (F, S)

**C138. The Berkeley Lectures on Energy: Energy from Biomass. (3)**

Two hours of lecture and one hour of discussion per week. *Prerequisites:* Chemistry 1B or 4B; Math 1B; Biology 1A. After an introduction to the different aspects of our global energy consumption, the course will focus on the role of biomass. The course will illustrate how the global scale of energy guides the biomass research. Emphasis will be placed on the integration of the biological aspects (crop selection, harvesting, storage and distribution, and chemical composition of biomass) with the chemical aspects to convert biomass to energy. The course aims to engage students in state-of-the-art research. Also listed as Bioengineering C181, Chemical and Biomolecular Engineering C195A, and Plant and Microbial Biology C124. (F)

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



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

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

**C150. Introduction to Materials Chemistry. (3)**

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

**C170L. Biochemical Engineering Laboratory. (3)**

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

**C178. Polymer Science and Technology. (3)**

Two hours of lecture and three hours of laboratory per week. *Prerequisite:* Junior standing. An interdisciplinary course on the synthesis, characterization, and properties of polymer materials. Emphasis on the molecular origin of properties of polymeric materials and technological applications. Topics include single molecule properties, polymer mixtures and solutions, melts, glasses, elastomers, and crystals. Experiments in polymer synthesis, characterization, and physical properties. Also listed as Chemical and Biomolecular Engineering C178. (F)

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

Students will receive one unit of credit for C182 after taking 125. Instructor's approval is required to enroll in C182 after completing 125. One hour of lecture and five hours of laboratory per week. *Prerequisites:* EPS 50 and 102 with grades of C- or higher (one of which may be taken concurrently); or two of the following: 120A, 120B, C130, or 130B with grades of C- or higher (one of which may be taken concurrently). Fluid dynamics, radiative transfer, and the kinetics, spectroscopy, and measurement of atmospherically relevant species are explored through laboratory experiments, numerical simulations, and field observations. Also listed as Earth and Planetary Science C182. (S)

**C191. Quantum Information Science and Technology. (3)**

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

**192. Individual Study for Advanced Undergraduates. (1-3)**

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

**H194. Research for Advanced Undergraduates. (2-4)**

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

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

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

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

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

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

#### Graduate Courses

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

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

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

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

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

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

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

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

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

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

**C230. Protein Chemistry, Enzymology, and Bio-organic Chemistry. (2)** Three hours of lecture per week for ten weeks or two hours of lecture per week for 15 weeks. *Prerequisite: Graduate standing or consent of instructor.* The topics covered will be chosen from the following: protein structure; protein-protein interactions; enzyme kinetics and mechanism; enzyme design. Intended for graduate students in chemistry, biochemistry, and molecular and cell biology. Also listed as Molecular and Cell Biology C214.

**C234. Green Chemistry: An Interdisciplinary Approach to Sustainability. (3)** Three hours of lecture per week. *Prerequisite: One year of chemistry, including a semester of organic chemistry.* Meeting the challenge of global sustainability will require interdisciplinary approaches to research and education, as well as the integration of this new knowledge into society, policymaking, and business. Green Chemistry is an intellectual framework created to meet these challenges and guide technological development. It encourages the design and production of safer and more

sustainable chemicals and products. Also listed as Environmental Science, Policy, and Management C234 and Public Health C234. (S)

**C236. Energy Solutions: Carbon Capture and Sequestration. (3)** Two hours of lecture and one hour of discussion per week. *Prerequisites: Chemistry 4B or 1B, Math 1B, Physics 7B, or equivalents.* After brief overview of the chemistry of carbon dioxide in the land, ocean, and atmosphere, the course will survey the capture and sequestration of CO<sub>2</sub> from anthropogenic sources. Emphasis will be placed on the integration of materials synthesis and unit operation design, including the chemistry and engineering aspects of sequestration. The course primarily addresses scientific and engineering challenges and aims to engage students in state-of-the-art research in global energy challenges. Also listed as Chemical and Biomolecular Engineering C295Z and Earth and Planetary Science C295Z. (F)

**C238. The Berkeley Lectures on Energy: Energy from Biomass. (3)** Two hours of lecture and one hour of discussion per week. *Prerequisites: Chemistry 1B or 4B; Math 1B; Biology 1A.* After an introduction to the different aspects of our global energy consumption, the course will focus on the role of biomass. The course will illustrate how the global scale of energy guides the biomass research. Emphasis will be placed on the integration of the biological aspects (crop selection, harvesting, storage and distribution, and chemical composition of biomass) with the chemical aspects to convert biomass to energy. The course aims to engage students in state-of-the-art research. Also listed as Bioengineering C281, Chemical and Biomolecular Engineering C295A, and Plant and Microbial Biology C224. (F)

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

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

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

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

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

**252A. Organometallic Chemistry I. (1)**

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

**252B. Organometallic Chemistry II. (1)**

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

**253A. Materials Chemistry I. (1)**

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

**253B. Materials Chemistry II. (1)**

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

**253C. Materials Chemistry III. (1)**

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

**254. Bioinorganic Chemistry. (1)**

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

**256. Electrochemical Methods. (1)**

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

**260. Reaction Mechanisms. (2)**

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

**261A. Organic Reactions I. (1)**

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

**261B. Organic Reactions II. (1)**

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

**261C. Organic Reactions III. (1)**

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

**262. Metals in Organic Synthesis. (1)**

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

**263A. Synthetic Design I. (1)**

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

**263B. Synthetic Design II. (1)**

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

**264A. Synthesis of Macromolecules. (1)**

Three hours of lecture per week for five weeks. *Prerequisite:* 200 or consent of instructor. The concepts of chain-growth and step-growth polymerizations. Radical, ionic, and metal catalyzed polymerizations. Living polymerization. Controlling macromolecular architecture: dendrimers, hyperbranched polymers, and crosslinked networks.

**264B. Properties and Applications of Macromolecules. (1)**

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

**265. Nuclear Magnetic Resonance Theory and Application. (1)**

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

**266. Mass Spectrometry. (1)**

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

**267. Organic Specialties. (1)**

Three hours of lecture per week for five weeks. *Prerequisite:*

*Graduate-level understanding of organic synthesis or consent of instructor.* A survey course focusing on an area of organic chemistry of importance, such as pharmaceutical chemistry, combinatorial chemistry, natural products chemistry, etc.

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

**270A. Advanced Biophysical Chemistry I. (1)**

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

**270B. Advanced Biophysical Chemistry II. (1)**

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

**271A. Chemical Biology I: Structure, Synthesis, and Function of Biomolecules. (1)**

Three hours of lecture per week for five weeks. *Prerequisite:* 200 or consent of instructor. This course will present the structure of proteins, nucleic acids, and oligosaccharides from the perspective of organic chemistry. Modern methods for the synthesis and purification of these molecules will also be presented. (S)

**271B. Chemical Biology II: Enzyme Reaction Mechanisms. (1)**

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

**271C. Chemical Biology III: Contemporary Topics in Chemical Biology. (1)**

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

**272A. Bio X-Ray I. (1)**

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



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

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

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

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

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

**299. Research for Graduate Students. (1-9)** Course may be repeated for credit. Laboratory. *Prerequisite:* Graduate standing. The facilities of the laboratory are available at all times to graduate students pursuing original

investigations toward an advanced degree at this University. Such work is ordinarily in collaboration with members of the staff. (F, S)

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

#### Professional Courses

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

**301. Pre-High School Chemistry Classroom Immersion. (1)** Course may be repeated for credit. One hour of lecture per week (average). Must be taken on a *satisfactory/unsatisfactory* basis. *Prerequisite:* Graduate standing. Provides training and opportunity for graduate students to make presentations in local public schools. Training ensures that presenters are aware of scientific information mandated by State of California for particular grade levels, and that presentations are intellectually stimulating, relevant to the classroom students' interests, and age-appropriate. Time commitment an average of 2-3 hours/week, but actual time spent concentrated during preparation and classroom delivery of presentations, which are coordinated between teachers' needs and volunteers' availability. (F, S)

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

**301B. Undergraduate Chemistry Instruction. (2)** Formerly 301. Course may be repeated once for credit. One hour of lecture and five hours of tutoring per week. Must be taken on a *passed/not passed* basis. *Prerequisites:* Sophomore standing; 1A, 1AL, and 1B with grades of B- or higher. 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. One hour of preparation meeting, four hours of instruction in the laboratory, and one hour of laboratory experiment preparation per week. Must be taken on a *passed/not passed* basis. *Prerequisites:* Sophomore standing and consent of instructor; 3B and 3BL with grades of B or higher. Undergraduate organic lab assistants help in the teaching of 3AL and 3BL. 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)

**301D. Undergraduate Chemistry Course Instruction. (1-2)** Course may be repeated for credit. Weekly meeting with instructor of tutored course and two to four hours of tutoring per week. Must be taken on a *passed/not passed* basis. *Prerequisites:* Junior standing or consent of instructor; completion of tutored course with a grade of B- or better. Tutoring of students enrolled in an undergraduate chemistry course. (F, S)

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

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

**303. Apprentice Teaching in Science. (2)** Course may be repeated for credit. Two hours of seminar per week. *Prerequisites:* Undergraduates may take the course with consent of instructor. Students must hold an approved teaching placement concurrently. The course is designed to support new science and mathematics teachers in earning a credential for teaching in California secondary schools. Students demonstrate that they have developed the skills to meet the state credentialing requirements by undertaking an inquiry project on their own teaching practice. Effective teaching methods for the science and mathematics classrooms are emphasized, including strategies for lesson planning, assessment, and English language learner support. (F, S)

## General Information

### Administration and Faculty

#### College of Chemistry Administration

##### Dean

Richard A. Mathies, Ph.D.

##### Executive Associate Dean

David E. Wemmer, Ph.D.

##### Undergraduate Dean

Marcin Majda, Ph.D.

##### Assistant Dean (Engineering and Facilities)

Alexander Shtromberg

##### Assistant Dean (College Relations)

Mindy Rex

##### Assistant Dean (Finance and Administration)

Suzanne Pierce

### Faculty of the Department of Chemical and Biomolecular Engineering

#### Professors

Nitash P. Balsara, Ph.D.

Alexis T. Bell, Sc.D.

Harvey W. Blanch, Ph.D.

Elton J. Cairns, Ph.D. (*Professor of the  
Graduate School*)

**Douglas S. Clark, Ph.D. (Chair)**

Jean M. J. Fréchet, Ph.D. (*Professor of the  
Graduate School*) (*Chemistry*)

David B. Graves, Ph.D.

Teresa Head-Gordon, Ph.D. (*Bioengineering,  
Chemistry*)

Enrique Iglesia, Ph.D.

Jay D. Keasling, Ph.D. (*Bioengineering*)

Roya Maboudian, Ph.D.

Susan J. Muller, Ph.D.

John S. Newman, Ph.D. (*Professor of the  
Graduate School*)

John M. Prausnitz, Ph.D., Dr. Ing., Sc.D.  
(*Professor of the Graduate School*)

Clayton J. Radke, Ph.D.

Jeffrey A. Reimer, Ph.D.

David V. Schaffer, Ph.D. (*Bioengineering,  
Neuroscience*)

Berend Smit, Ph.D. (*Chemistry*)

Morton M. Denn, Ph.D. (*Emeritus*)

Simon L. Goren, D.Eng. (*Emeritus*)

Edward A. Grens, Ph.D. (*Emeritus*)

C. Judson King, Sc.D. (*Emeritus*)

Scott Lynn, Ph.D. (*Emeritus*)

Michael C. Williams, Ph.D. (*Emeritus*)

#### Associate Professors

Alexander Katz, Ph.D.

Rachel A. Segalman, Ph.D.

#### Assistant Professors

Jhieh-Wei Chu, Ph.D.

Danielle Tullman Ercek, Ph.D.

Wenjun Zhang, Ph.D.

#### Adjunct Professors

Keith Alexander, Ph.D.

Brian L. Maiorella, Ph.D.

#### Lecturers

Carlo Alesandrini, Ph.D.

Shannon Ciston, Ph.D.

Henrik Wallman, Ph.D.

#### Visiting Professor

Gregory Schoofs, 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 and Engineering*)  
Richard A. Andersen, Ph.D.  
John Arnold, Ph.D.  
Robert G. Bergman, Ph.D.  
Carolyn R. Bertozzi, Ph.D. (*Molecular and Cell Biology, UC Berkeley; Cellular and Molecular Pharmacology, UCSF*)  
Carlos J. Bustamante, Ph.D. (*Physics, Molecular and Cell Biology*)  
Jamie H. Doudna Cate, Ph.D. (*Molecular and Cell Biology*)  
Joseph Cerny, Ph.D.  
David Chandler, Ph.D.  
Ronald C. Cohen, Ph.D. (*Earth and Planetary Science*)  
Jennifer A. Doudna, Ph.D. (*Molecular and Cell Biology*)  
Graham R. Fleming, Ph.D.  
Jean M. J. Fréchet, Ph.D. (*Professor of the Graduate School*) (*Chemical and Biomolecular Engineering*)  
Jay T. Groves, Ph.D.  
Charles B. Harris, Ph.D.  
Robert A. Harris, Ph.D. (*Professor of the Graduate School*)  
John Hartwig, Ph.D.  
Martin Head-Gordon, Ph.D.  
Teresa Head-Gordon, Ph.D. (*Bioengineering, Chemical and Biomolecular Engineering*)  
Sung-Hou Kim, Ph.D. (*Professor of the Graduate School*)  
Jack F. Kirsch, Ph.D. (*Professor of the Graduate School*) (*Molecular and Cell Biology*)  
Judith P. Klinman, Ph.D. (*Professor of the Graduate School*) (*Molecular and Cell Biology*)  
John Kuriyan, Ph.D. (*Molecular and Cell Biology*)  
Stephen R. Leone, Ph.D. (*Physics*)  
William A. Lester Jr., Ph.D. (*Professor of the Graduate School*)  
Jeffrey R. Long, Ph.D.  
Marcin Majda, Ph.D.  
Michael A. Marletta, Ph.D. (*Molecular and Cell Biology, UC Berkeley; Cellular and Molecular Pharmacology, UCSF*)  
Richard A. Mathies, Ph.D.  
William H. Miller, Ph.D. (*Professor of the Graduate School*)  
Luciano G. Moretto, Ph.D.  
**Daniel M. Neumark, Ph.D. (Chair)**  
Heino Nitsche, Ph.D.  
Alexander Pines, Ph.D.  
Kenneth N. Raymond, Ph.D. (*Professor of the Graduate School*)  
Richard J. Saykally, Ph.D.  
Kevan Shokat, Ph.D. (*Cellular and Molecular Pharmacology, UCSF*)  
Berend Smit, Ph.D. (*Chemical and Biomolecular Engineering*)



Angelica M. Stacy, Ph.D.  
T. Don Tilley, Ph.D.  
Ignacio Tinoco Jr., Ph.D. (*Professor of the Graduate School*)  
F. Dean Toste, Ph.D.  
K. Peter C. Vollhardt, Ph.D.  
David E. Wemmer, Ph.D.  
K. Birgitta Whaley, Ph.D.  
Evan R. Williams, Ph.D.  
Omar Yaghi, Ph.D.  
Peidong Yang, Ph.D. (*Materials Science and Engineering*)  
Paul A. Bartlett, Ph.D. (*Emeritus*)  
Robert E. Connick, Ph.D. (*Emeritus*)  
John E. Hearst, Ph.D. (*Emeritus*)  
Clayton H. Heathcock, 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*)  
Norman E. Phillips, Ph.D. (*Emeritus*)  
John O. Rasmussen, Ph.D. (*Emeritus*)  
Kenneth Sauer, Ph.D. (*Emeritus*)  
Charles V. Shank, Ph.D. (*Emeritus*) (*Physics, EECS*)  
David A. Shirley, Ph.D. (*Emeritus*)  
Herbert L. Strauss, Ph.D. (*Emeritus*)  
Andrew Streitwieser Jr., Ph.D. (*Emeritus*)

### Associate Professors

Kristie A. Boering, Ph.D. (*Earth and Planetary Science*)  
Christopher J. Chang, Ph.D. (*Pharmaceutical Chemistry, UCSF*)  
Matthew B. Francis, Ph.D.  
Phillip L. Geissler, Ph.D.  
Richmond Sarpong, Ph.D.

### Assistant Professors

Michelle C. Chang, Ph.D. (*Molecular and Cell Biology*)  
Tanja Cuk, Ph.D.  
Felix Fischer, Ph.D.  
Naomi Ginsberg, Ph.D.  
Ming Hammond, Ph.D. (*Molecular and Cell Biology*)  
Bryan A. Krantz, Ph.D. (*Molecular and Cell Biology*)  
Thomas J. Maimone, Ph.D.  
David Savage, Ph.D. (*Molecular and Cell Biology*)  
Ting Xu, Ph.D. (*Materials Science and Engineering*)

### Adjunct Professor

Anne Baranger, Ph.D.

### Lecturers

Michelle Douskey, Ph.D.  
Steven Pedersen, Ph.D.  
MaryAnn Robak, Ph.D.

## College of Chemistry Breadth Requirement Course List

### Group I (Reading and Composition)

Courses taken to satisfy Group I also satisfy the Reading and Composition requirement. All courses are taught in English.

#### African American Studies

R1A-R1B. Freshman Composition (4-4)

#### Anthropology

R5B. Reading and Composition in Anthropology (4)

#### Asian American and Asian Diaspora Studies

R2A-R2B. Reading and Composition (4-4)

#### Celtic Studies

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

#### Chicano Studies

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

#### Classics

R44. Roots of Western Civilization (5)

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

#### College Writing Programs

R1A. Accelerated Reading and Composition (6)

R4A. Reading and Composition (4)

R4B. Reading, Composition, and Research (4)

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

#### 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)

R50. Freshman and Sophomore Studies (4)

*Note:* English R50 satisfies the second-level of the Reading and Composition requirement.

#### Environmental Design

R3B. Reading and Composition in Sustainability and Environmental Design (4)

#### Film and Media

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

#### French

R1A-R1B. English Composition in Connection with the Reading of Literature (4-4)

#### Gender and Women's Studies

R1B. Reading and Composition (4)

#### German

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

#### History

R1. The Practice of History (4)

*Note:* Satisfies the second-level of the Reading and Composition requirement.

#### History of Art

R1B. Reading and Writing About Visual Experience (4)

#### Italian Studies

R5A-R5B. Italy at Home and Abroad (4-4)

#### Legal Studies

R1A-R1B. Reading and Composition in Connection with the Law as a Social Institution (4-4)

#### Letters and Science

R44. Western Civilization (5)

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

#### Linguistics

R1B. Endangered Languages: What We Lose When a Language Dies (4)

#### Music

R1B. Reading and Writing about Music (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)

#### Philosophy

R1B. Reading and Composition Through Philosophy (4)

#### Rhetoric

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

#### Scandinavian

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

#### Slavic Languages and Literatures

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

#### South and Southeast Asian Studies

R5A. Self, Representation, and Nation (4)

R5B. Under Western Eyes (4)

#### South Asian

R5A. Great Books of India (4)

R5B. India in the Writer's Eye (4)

#### Spanish

R1A-R1B. Reading and Composition Through Readings from the Spanish-Speaking World (4-4)

#### Theater, Dance, and Performance Studies

R1A-R1B. Performance: Writing and Research (4-4)

## Group II (Humanities and Social Sciences)

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

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

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

#### Aerospace Studies

2A and 2B

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

#### African American Studies

4A-C31B, 100-118, 121-138, 139\*, 142A-163, C178

#### American Studies

10, 10AC, 101, 101AC, 102, 110\*, C112A, C112B, C112F, 139AC, C152, C172, C174, 178AC, 179AC

#### Anthropology

2, 2AC, 3, 3AC, 111, 114-119, 121A-C, 122A-F, 123A-D, 124A, 124AC, C125B, 128-130, 132, 134, 136-166, 169B-171, 172AC, 174AC-189

#### Arabic

1A, 1B, 15A, 15B, 20A, 20B, 100A, 100B, 104B, 105B, 108, 111A, 111B, 190A-K

#### Architecture

100A, 100B, 101, 109, 110AC, 119, 139, 170A, 170B, 173, 175

#### Asian American Studies

20A-C, 120-190

#### Asian Studies

10, 147, 148, 150

#### Buddhist Studies

C50, 114, C114, C115, C120, C122, C124, C126, C128, C130, C140, C174

#### Business Administration (UGBA)

10, 39AC, 101A, 101B, 105, 107, 118, 155, 170, C172, 175, 178, 184

#### Catalan

101

#### Celtic Studies

15, 16, 70, 85, 86, 102A, 102B, 105A, 105B, 119B, 125, 128, 129, 138, 139, 144A, 144B, 145A, 145B, 146A, 146B, C168, 173

**Chicano Studies**

6A, 6B, 20, 40, 50, 70, 101, 130, 133, 135A-C, 141, 142, 143, 145, 148, 149, 150A, 150B, 159, 161, 162, 163, 165, 172, 174, 176, 179, 180

**Chinese**

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

**City and Regional Planning**

110, 111, 112A, 113A, 113B, C114, 115, 116, 118AC

**Civil and Environmental Engineering**

C154, 167

**Classics**

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

**Cognitive Science**

1, C100, C101, C102, C103, C104, C108, C110, C124, C147

**College Writing Programs**

25AC, 50AC, 110, 150AC

**Comparative Literature**

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

**Computer Science**

C182

**Cuneiform**

any

**Demography**

110, C126, 145AC, C164, C175

**Development Studies**

any

**Dutch**

1, 2, 107, 110, 125, 140, C164, 166, 170, C170, 173, 176, C178, C179

**East Asian Languages and Cultures**

C50, 101-109, C120, C122, C124, C126, C128, C130, 180, 181

**East European Studies**

1A, 1B, 2A, 2B, 100

**Economics**

any

**Education**

40AC, 75AC, 100, 114A, C116, 140AC, C145, 180, C181, 182AC, 184, 185, 186AC, 187, 189, 190

**Egyptian**

any

**Energy and Resources Group**

100, C100, 102, 151, 162, C180, 190

**Engineering**

120, 124, 130AC, 191, 195

**English**

any, except R1A, R1B, R50

**Environmental Design**

1, C169A, C169B

**Environmental Economics and Policy**

C1, 100, C101, C118, 140AC, 141, 142, 143, 145, C151, 152, 154, 161, 162, C175, C180, C181

**Environmental Science, Policy, and Management**

C10, C11, C12, 50AC, 60, 100, 102A, 102B, 102C, 102D, C103, C104, 151, 155, C159, 160AC, 161, 162, 163AC, 165, 166, 167, C167, 182, 183, 184, 185, 186, 188, C191

**Environmental Sciences**

10

**Ethnic Studies**

10AC, 11AC, 20AC, 21AC, 41AC, C73AC, 100, 122AC, 136, 144AC, 147, 159AC, 190

**Eurasian Studies**

1A, 1B, 2A, 2B, 101A, 101B, 102A, 102B

**Filipino**

any

**Film and Media**

any, except R1A, R1B

**French**

1-4, 13, 14, 35, 43B, 102, 103A-112B, 114A-119B, 120A-124A, 138-145, 146A, 150A-162A, 170-174, 175A-180D, 183A-185

**Gender and Women's Studies**

10, 14, C15, 20, 40, 50AC, 100AC, 101, 102, 103, 104, 111, 116AC, 120, 125, 130AC, 131, 133AC, 139, 140, 141, 142, 143, C146, C153A, C153B

**Geography**

10, C15, 20, 30, C32, 37, 50AC-130, C152-159AC, C160A, C160B, 165-168, 177, 180, 181

**German**

1, 2, 3, 4, 40, C75, 100, 101, 105, C106, C109-123, 131, 140, 141, 151-162, 168-170, 175B, C179

**Global Poverty and Practice**

105, 115

**Greek**

1, 2, 10, 40, 100, 101, 102, 105, 115, 116, 117, 120, 121, 122, 123, 125

**Health and Medical Sciences**

C133

**Hebrew**

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

**Hindi-Urdu**

1A, 1B, 2A, 2B, 100A, 100B, 101A, 101B, 103A, 103B, 104A, 104B

**History**

any, except R1

**History of Art**

any, except R1B

**Industrial Engineering**

170, 171

**Information**

C103, 142AC, 146, 182AC

**Integrative Biology**

C156

**Interdisciplinary Studies**

60, 61, 100A, 100B, C100C, 100E-H, C145

**International and Area Studies**

45, 102, 115, C118, 120, 143, C145, 150, C175

**Iranian**

any

**Italian Studies**

1, 2, 3, 4, 12, 30, 40, 50, 70, 101A, 101B, 103, 104, 110, 112, 115, 117, 120, 130A, 130B, 160, 170, 175

**Japanese**

1A, 1B, 10A, 10B, 100A, 100B, 101, 102, 103, 104, C115, 120, 130, 132, 140, 142, 144, 146, 155, 159, 160, 161, 162, C174, C176, 185, 186, 188, 189

**Jewish Studies**

39A, 101, 120, C179

**Journalism**

C101, 102AC, C141

**Khmer**

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

**Korean**

1A, 1B, 10A, 10B, 100A, 100B, 101, 102, 150, 155, 157

**Landscape Architecture and Environmental Planning**

101, 102, 103, 110, 111, 121, 130, 140, 141AC, 170

**Latin**

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

**Latin American Studies**

10, 150

**Legal Studies**

any, except R1A, R1B

**Lesbian, Gay, Bisexual, and Transgender Studies**

any

**Letters and Science**

5, 17, 40AC, C60T, 80A-S, C101, C160T, C160U, C160V, 170AC, 180AC, C180T

**Linguistics**

any, except R1B, C160

**Malay/Indonesian**

any

**Mathematics**

160

**Media Studies**

any

**Medieval Studies**

150

**Middle Eastern Studies**

20, 130, 150

**40 Military Affairs**  
1, 20, 123, 145A, 154

**Molecular and Cell Biology**  
41, 61

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

**Native American Studies**  
71, 72, C73AC, 90, 100, 101, 102, 104, 110, 120A, 120AC, 149, 151, 152, C152, 155, 158, 175, 176, 178AC, 182, 190

**Naval Science**  
2, 3

**Near Eastern Studies**  
10, 15, 18, C26, 102A-106B, 109, 110, C120A-175

**New Media**  
150AC

**Nutritional Science and Toxicology**  
104, 135, C159

**Peace and Conflict Studies**  
10, 100, 125AC, 127A, 128AC, 135, 149, 150, 151, 154, 154AC, 164A

**Persian**  
1A, 1B, 100A, 100B, 101A, 101B, 102A, 102B, 103A, 103B, 104A, 104B, 105, 120

**Philosophy**  
any, except R1B, 12A, 12B

**Plant and Microbial Biology**  
10

**Political Economy**  
any

**Political Science**  
any, including 179

**Portuguese**  
11, 12, 101A, 101B, 102, 103, 104, 107B, 112, 113, 114, 128, 135

**Practice of Art**  
23AC, 162, 164, C179

**Psychology**  
1, 2, 14, 101-110, C120, C124, C129-141, 146-168, 180, 182

**Public Health**  
14, 103, 105, 107, 112, 114, 115, 126, 130AC, 150A, 150B, 150D, 150E, C155, C160, 180, 181

**Public Policy**  
101, C103, 117AC, C142, 156, C162, C164, 179-C184

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

**Religious Studies**  
90A, 90B, C90B, C103, C104, C108, C109, C111, C118, C119, 120A, C124, C132, C133, C135, C161, C162, C163, C164, C165, C166, 171AC, 173AC, C182, 190

**Rhetoric**  
20, 41AC, 103A-182

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

**Scandinavian**  
1A, 1B, 2A, 2B, 3A, 3B, 4A, 4B, 100A, 100B, 102A, 102B, C107, C108, C114, 115, 116, 120, 123, 125, 127, 128, 150, C160, 165, 170, 190AC

**Semitics**  
any

**Slavic Languages and Literatures**  
1-4, 6A, 6B, 25A-28B, 36, 45, 46, 50, 101, 103A, 103B, 106A, 106B, 114-133, 134A-N, 137-151, 160, 161, 170, 171, 181-190

**Social Welfare**  
any

**Sociology**  
any

**South and Southeast Asian Studies**  
1A, 1B, C51, C52, C145, C186

**South Asian**  
108, C114, 121, C122, C123, 124, C127, C128, C140, C141, C142, 143, 144, C145, 146, 152

**Southeast Asian**  
10A, 10B, 128, 129, 130, C141A, C141B, C141C, C164

**Spanish**  
1-4, 8, 21, 22, 25-39, 100-102B, 104A-123B, 131-162, 164, 165AC, C178, 179, C179, 185

**Tagalog**  
any

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

**Telugu**  
1A, 1B

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

**Theater, Dance, and Performance Studies**  
25AC, 26, 52AC, 66\*, C107, C108, 119, 121, 122, 125, 126, C131A, C131B, 145, 151B, 153A, 153B, 166\*

**Tibetan**  
1A, 1B, 10A, 10B, 100A, 100B, 110A, 110B, C114

**Turkish**  
1A, 1B, 100A, 100B, 101A, 101B

**Undergraduate and Interdisciplinary Studies**  
80A, 110, 112, C132, C133, C135, C136, C137, C153, C155, 156AC, 161, 162, 162A-N, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 176, 177, 187

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

**Visual Studies**  
C185A, 185X

**Yiddish**  
101, 102, 103

## Notes

### Unacceptable Courses

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

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

### Foreign Language

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

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

### Additional Courses

Any course that satisfies the American Cultures requirement or the American History and Institutions requirements will be accepted toward satisfaction of the Breadth requirement.

Students can petition for acceptance of a freshman seminar course.

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



## ADVANCED PLACEMENT TESTS — CREDIT INFORMATION

Name of Test ( <sup>1</sup> Credit granted by UC)	Score	UC Berkeley Course(s) or Requirement(s) Satisfied
<b>Chemistry</b> (5.3 units)	3 or higher	none
<sup>2</sup> <b>Math:</b> <b>Calculus AB</b> <b>Calculus AB SUB</b> (2.7 units)	3 or higher	Math 1A
<sup>2</sup> <b>Math:</b> <b>Calculus BC</b> (5.3 units)	3 or 4 5	Math 1A Math 1A and 1B
<sup>2</sup> <b>Physics B</b> (5.3 units)	3 or higher	none
<sup>2</sup> <b>Physics C:</b> <b>Mechanics</b> <b>Electricity &amp; Magnetism</b> (2.7 units each)	Sum of two tests: 8 or less 9 or higher	none Physics 7A (Consider taking the physics honors sequence.)
<sup>2</sup> <b>English</b> <b>Literature &amp; Composition</b> (5.3 units)	3 4 5	Entry-Level Writing  <sup>3</sup> Entry-Level Writing <b>and</b> a first-level Reading and Composition course (e.g., English R1A) with 4 units of credit toward the Breadth requirement (Group I)  <sup>3</sup> Entry-Level Writing <b>and</b> first- and second-level Reading and Composition courses (e.g., English R1A and Rhetoric R1B) with 5.3 units of credit total toward the Breadth requirement (Group I)
<sup>2</sup> <b>English</b> <b>Language &amp; Composition</b> (5.3 units)	3 4 or 5	Entry-Level Writing  <sup>3</sup> Entry-Level Writing <b>and</b> a first-level Reading and Composition course (e.g., English R1A) with 4 units of credit toward the Breadth requirement (Group I)
<b>Art:</b> <b>History of Art</b> <b>History:</b> <b>European</b> <b>United States</b> <b>World</b> <b>Music Theory</b> (5.3 units each)	3 or higher	3 units of credit (for each test) toward the Breadth requirement (Group II)
<b>Economics:</b> <b>Microeconomics</b> <b>Macroeconomics</b> <b>Government &amp; Politics:</b> <b>Comparative</b> <b>United States</b> <b>Human Geography</b> <b>Psychology</b> (2.7 units each)	3 or higher	2.7 units of credit (for each test) toward the Breadth requirement (Group II)

Name of Test ( <sup>1</sup> Credit granted by UC)	Score	UC Berkeley Course(s) or Requirement(s) Satisfied
<b>French Literature</b> <b>Spanish Literature</b> (5.3 units each)	3 or higher	For <b>chemical engineering</b> majors, 3 units of credit (for each test) toward the Breadth requirement (Group II)  <sup>4</sup> For <b>chemistry</b> or <b>chemical biology</b> majors, each test satisfies either the Foreign Language requirement or 3 units of credit toward the Breadth requirement (Group II)
<b>Chinese Language and Culture</b> <b>French Language</b> <b>German Language</b> <b>Italian Language and Culture</b> <b>Japanese Language and Culture</b> <b>Spanish Language</b> (5.3 units each)	3 or higher	For <b>chemical engineering</b> majors, 5.3 units of credit (for each test) toward the Breadth requirement (Group II) <i>Note:</i> For chemical engineering majors, no more than 6 units of foreign language may be counted toward the Breadth requirement (Group II)  <sup>4</sup> For <b>chemistry</b> or <b>chemical biology</b> majors, each test satisfies either the Foreign Language requirement or 5.3 units of credit toward the Breadth requirement (Group II)
<b>Latin:</b> <b>Literature</b> <b>Vergil</b> (2.7 units each)	3 or higher	For <b>chemical engineering</b> majors, 2.7 units of credit (for each test) toward the Breadth requirement (Group II)  <sup>4</sup> For <b>chemistry</b> or <b>chemical biology</b> majors, each test satisfies either the Foreign Language requirement or 2.7 units of credit toward the Breadth requirement (Group II)
<sup>2</sup> <b>Art: Studio Art</b> (5.3 units each)	3 or higher	Does not satisfy any college/major requirement
<b>Biology</b> (5.3 units)	3 4 or 5	Does not satisfy any college/major requirement  For <b>chemical biology</b> or <b>chemical engineering</b> majors, 1A and 1AL  For <b>chemistry</b> majors, does not satisfy any college/major requirement  <i>Note:</i> With a score of 4 or 5, students receive subject credit for Biology 1A, 1AL, and 1B as prerequisite to other courses.  Consult the Career Center regarding the use of tests for admission to professional schools.
<sup>2</sup> <b>Computer Science A</b> (1.3 units) <sup>2</sup> <b>Computer Science AB</b> (2.7 units)	3 or higher	Does not satisfy any college/major requirement
<b>Environmental Science</b> <b>Statistics</b> (2.7 units each)	3 or higher	Does not satisfy any college/major requirement

<sup>1</sup> 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.

<sup>2</sup> Students who have passed both the English Literature and Composition and the English Language and Composition tests will receive a maximum of only 5.3 units of credit (total) for these tests. This is also true for the Math Calculus AB and Math Calculus BC tests, for the Physics B and Physics C tests, and for the Art Studio tests. Students who have passed both the Computer Science A and the Computer Science AB tests will receive a maximum of only 2.7 units of credit (total) for these tests.

<sup>3</sup> **Reading and Composition Requirements:**

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

<sup>4</sup> For the **chemistry** or **chemical biology** major, credit for an elementary foreign language cannot be applied to the Breadth requirement if the same foreign language is used to satisfy the Foreign Language requirement.

---

## Nondiscrimination Statement

The University of California, in accordance with applicable Federal and State law and the University's nondiscrimination policies, does not discriminate on the basis of race, color, national origin, religion, sex (including sexual harassment), gender identity, pregnancy/childbirth and medical conditions related thereto, disability, age, medical condition (cancer-related), ancestry, marital status, citizenship, sexual orientation, or status as a Vietnam-era veteran or special disabled veteran. This nondiscrimination statement covers admission, access, and treatment in University programs and activities. It also covers faculty (Senate and non-Senate) and staff in their employment.

The Campus Climate and Compliance (CCAC) office may be contacted regarding discrimination issues. Sexual or racial harassment, hostile environment, LGBT, hate or bias issues may be directed to Denise W. Oldham, Interim Director and Title IX/VI Compliance Officer, at [dwoldham@berkeley.edu](mailto:dwoldham@berkeley.edu) or (510) 643-7985. Disability issues may be directed to the Disability Resolution Officer at [esc@berkeley.edu](mailto:esc@berkeley.edu) or (510) 642-2795. More information may also be found at [ccac.berkeley.edu](http://ccac.berkeley.edu).

---

## The Jeanne Cleary Act

The University of California, Berkeley, publishes a reference guide of safety information and procedures, annual campus crime statistics, and emergency/disaster preparedness information. For a copy of the campus safety guide, *Safety Counts*, please contact the University of California Police Department, Berkeley, by phone at (510) 642-6760 or by e-mail at [police@berkeley.edu](mailto:police@berkeley.edu). You can also download a PDF of *Safety Counts* at [police.berkeley.edu/safetycounts](http://police.berkeley.edu/safetycounts).

---

## Photo/Image Credits

Michael Barnes: cover (professor with student) and pages 3, 6, 11, 15, 19, 20, 23, 24, 28, 31, 32, 36, 37, 41; Kathleen Durkin: cover (far right); Yimin Li: cover (far left); Steve McConnell/UC Berkeley Public Affairs: page 4; David Schmitz: cover (beakers and watermark of bottles of chemicals) and pages 9, 17, 35; Peg Skorpinski: page 2

**College of Chemistry**

University of California, Berkeley  
420 Latimer Hall #1460  
Berkeley, CA 94720-1460

**Undergraduate Advising Office:**

University of California, Berkeley  
College of Chemistry  
4th Floor Latimer Hall #1460  
Berkeley, CA 94720-1460  
(510) 642-7919

**Department Offices:**

University of California, Berkeley  
Department of Chemical and  
Biomolecular Engineering  
201 Gilman Hall #1462  
Berkeley, CA 94720-1462  
(510) 642-2291

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

[chemistry.berkeley.edu](http://chemistry.berkeley.edu)

