

must complete 54 units of graduate courses in chemical engineering that are approved by the chemical engineering faculty. The 54 units will consist of no more than 24 units from ChE 101, 103 abc, 105, 118, and 120, and at least 36 units from ChE 151 ab, ChE 152, ChE/Ch 164, ChE/Ch 165, and a list of chemical engineering courses provided by the option representative. A 3.0 GPA is required for the courses taken.

*Graduate Studies Adviser, Option Representative, and Chemical Engineering Graduate Studies Committee.* During graduate studies, students will interact with several members of the chemical engineering faculty. The most intensive interaction will be with the research adviser, who will advise on all aspects of Ph.D. research and course work and will approve various formal requirements. The student will also interact with the members of the thesis review committee on matters relating to research progress, and the ChE option representative on any other matters concerning graduate studies. During the first year, the ChE option representative will advise the students about choice of research adviser, choice of courses, and Ph.D. qualifying exams. The option representative is responsible for GRA (graduate research assistantship) or GTA (graduate teaching assistantship) assignments, beyond the first year, and for approval of the Candidacy and Thesis Review Committees and other formal requirements for the M.S. and Ph.D. degrees. Students may contact either of these two faculty members regarding any questions or problems. In a case where the relationship between a student and his or her research adviser becomes strained and the student desires advice or help from other faculty, he or she should consult with the Chemical Engineering Graduate Studies Committee, consisting of the option representative, the graduate studies adviser, and the option executive officer.

#### *Additional Information*

Additional information about graduate study requirements and procedures is provided in the chemical engineering graduate studies guide, distributed annually to first-year chemical engineering graduate students.

## **Chemistry**

### *Aims and Scope of the Graduate Program*

The Caltech Chemistry option offers a program of graduate study leading to the Ph.D. degree, with the goal of preparing students for a lifetime of independent research and scientific leadership in the chemical sciences, through careers in academia, industry or government. Modern chemistry strives to achieve a molecular-level understanding of the natural world and thus forms the basis for much of modern science, including biology, medicine, materials, nanotechnology, energy and environment. The program of study, while anchored in the traditional areas of organic chemistry, inorganic chemistry, chemical biology, biochemistry and biophysics, chemical physics and theoretical chemistry, is flexible and highly interdisciplinary.

The graduate program in chemistry emphasizes research. This emphasis reflects the Institute's traditional leadership in chemical research and the conviction that has permeated the Division of Chemistry and Chemical Engineering from its founding, that participation in original research is the best way to awaken, develop, and give direction to creativity.

The program is designed to encourage students to begin their research early in their first year. Students can elect to do research that crosses the boundaries of traditionally separate areas of chemistry, for in this relatively compact division, they are encouraged to go where their scientific curiosity drives them. A thesis that involves more than one adviser is not uncommon, and interdisciplinary programs with biology, physics, geology, chemical engineering, and environmental science and engineering science are open and encouraged.

An extensive program of seminars will enable students to hear of and discuss notable work in chemical physics, organic chemistry, inorganic chemistry and electrochemistry, organometallic chemistry, and biochemistry and molecular biophysics. Graduate students are also encouraged to attend seminars in other divisions.

#### *Learning Outcomes*

Students upon whom are conferred the Ph.D. degree have provided evidence of independent scholarship and scientific creativity through the performance of original research, which is described in their doctoral thesis and defended orally. Students must also demonstrate an ability to conceive new research directions by preparing and defending a set of written research propositions.

#### *Course Program*

A student is required to complete at least five courses, each being nine units or more, in science or engineering. At least one course must be in a field substantially outside the research area of the student. Courses may be either inside or outside the chemistry option, must be numbered 100 or greater, and must be taken on a letter-grade basis with a grade of B or above. The student should discuss, with his or her advisor, which courses best serve his or her individual needs. The program of courses must be approved by the research advisor and by the Chemistry Graduate Study Committee.

#### *Master's Degree*

Students are not ordinarily admitted to graduate work leading to an M.S. degree. Under special circumstances, and with prior approval of the Graduate Study Committee, a master's degree can be obtained. All master's programs for the degree in chemistry must include at least 45 units of chemical research and must satisfy the Course Program described above. The remaining electives may be satisfied by advanced work in any area of mathematics, science or engineering, or by chemical research. Two copies of a satisfactory thesis describing this research, including a one-page digest or summary of the main

results obtained, must be submitted to the divisional graduate secretary at least 10 days before the degree is to be conferred. In addition, the fulfillment of the thesis requirement must be signed off by a designated faculty member on the M.S. candidacy form and a final copy of the thesis submitted to the Graduate Office no later than two weeks before the degree is to be conferred. The copies of the thesis should be prepared according to the directions formulated by the dean of graduate studies and should be accompanied by a statement of approval of the thesis, signed by the advisor directing the research and by the chair of the Chemistry Graduate Study Committee.

#### *B.S./M.S. Joint Degree*

Under special circumstances, exceptional undergraduate students may be awarded a joint B.S./M.S. degree in Chemistry. Students with demonstrated academic excellence may petition the Chemistry Graduate Studies Committee and the Chemistry Curriculum and Undergraduate Studies Committee. Petitions should be submitted no later than Add Day of the Spring of their second year, but students are strongly encouraged to contact the Graduate Option Representative as early as possible, who will assign them to an academic graduate advisor. They must fulfill all institute and option requirements for both the B.S. and M.S. degrees; no courses can satisfy B.S. and M.S. degree requirements simultaneously. Coursework for the M.S. portion of the degree must be taken from courses numbered 100 and above on a letter-grade basis, and passed with a grade point average of 3.5 or better. As a junior, students must take 27 units of research in Ch82 and complete all requirements including a written thesis and oral presentation. The thesis must be judged exceptional by a committee comprising the research advisor, graduate academic advisor, Ch82 instructor, and Chair of the Graduate Studies Committee, in order to continue with the B.S./M.S. program. As a senior, the students must take 27 units of research as Ch182 and is expected to satisfy all requirements, including submission of a Master's Thesis and oral presentation. No additional units of research beyond these 54 units can be used to meet the course requirements.

#### *Degree of Doctor of Philosophy*

*Selecting a Research Project.* Soon after a new graduate student arrives in the laboratories, he or she attends a series of orientation seminars that introduce students to the active research interests of the faculty. Students then meet with each of five or more faculty whose fields attract them, to discuss in detail potential research problems. They eventually settle upon the outlines of a research problem that interests them and select a specific research advisor (or set of co-advisors). Neither students nor faculty can make a commitment to an advisor-advisee relationship prior to the end of the first month of the fall term. Students typically begin research during their first academic year.

*Candidacy.* To be recommended for candidacy for the doctor's degree in chemistry, in addition to demonstrating an understanding and knowledge of the fundamentals of chemistry, a student must give satisfactory evidence of proficiency at a high level in the primary field of interest, as approved by the division. This is accomplished by an oral candidacy examination, which must be held during or before the fifth term of graduate residence (excluding summer terms). The candidacy committee shall consist of the thesis advisor(s) and two additional faculty members; at least two of the three members must be chemistry faculty. The committee should be considered as a resource for the student for the remainder of his or her studies. At the candidacy examination, a student is asked to demonstrate scientific and professional competence and promise by discussing a research report and propositions as described below.

The research report should describe progress and accomplishments to date and plans for future research. Two original research propositions, or brief scientific theses, must accompany the report, and at least one must be well removed from the student's field of research. These propositions should reflect his or her breadth of familiarity with the literature, originality, and ability to pose and analyze suitable scientific research problems. The research report and propositions must be in the hands of the examining committee one week before the examination.

The result of the candidacy examination may be either (a) pass, (b) fail, or (c) conditional. Conditional status is granted when the committee decides that deficiencies in a student's research report, propositions, or overall progress can be remedied in a specific and relatively brief period of time. In order to change conditional to pass status, the student must correct the indicated deficiencies or in some cases schedule a new examination the following term. He or she must be admitted to candidacy at least three terms before the final oral examination. A student cannot continue graduate work in chemistry (nor can financial assistance be continued) past the end of the sixth term of residence without being admitted to candidacy, except by petitioning the division for special permission. This permission, to be requested by a petition submitted to the Graduate Study Committee stating a proposed timetable for correction of deficiencies, must be submitted before registration for each subsequent term (including the summer following the sixth term of residence) until admission to candidacy is achieved.

*Language Requirement.* There is no formal foreign language requirement for the Ph.D. in chemistry. However, the division believes strongly in the professional importance to chemists of knowledge of foreign languages and encourages their study prior to graduate work or while in graduate school.

*Ph.D. Thesis Committee.* In the third year, the student in consultation with their advisor will form their Ph.D. thesis committee. This committee will comprise at least four faculty members and will generally consist of the original candidacy committee plus an additional

member of the faculty; at least three of the members must be from the chemistry option. The student must meet with their committee annually, beginning in the third year. At these informal meetings, the student will update the committee on the status of their research.

*Fourth Year Progress Meeting.* Before the thirteenth academic term of graduate residence (excluding summer terms), the student will be expected to demonstrate satisfactory progress in the course of thesis research. To this end, an informal meeting with the Ph.D. thesis committee will be held, at which time the student will present an oral summary of research completed to date as well as an outline of future research plans. Following the presentation, an appropriate timetable for completion of the degree requirements will be discussed and agreed upon. If the student has not progressed sufficiently, completion of the Ph.D. may be considered inappropriate.

*Length of Graduate Residence.* Any graduate student who anticipates a need to register for a twenty-fourth academic term must hold a meeting of his or her thesis committee and present the institute-required petition for permission to register that includes a plan of action for the period of the requested registration and a specific date for the completion of the degree requirements. This petition must be approved by the Thesis Committee, by the chair of the Chemistry Graduate Study Committee and, in cases where financial support is an issue, by the executive officer or division chair, before it is forwarded to the Dean of Graduate Studies. Financial support of graduate students who are required to petition to register will not normally be provided through teaching assistantships. Failure to complete the degree requirements by the date specified in the petition would require the entire approval process to be repeated. This process must be repeated for every subsequent year.

*Thesis and Final Examination.* The final examination will consist in part of the oral presentation and defense of a brief résumé of the student's research and in part of the defense of a set of propositions he or she prepares. Three original research propositions are required. No more than one of these may be a carryover from the candidacy examination, and at least one must be well removed from the field of research. Each proposition shall be stated explicitly and the argument presented in writing with adequate documentation. The propositions should display originality, breadth of interest, and soundness of training; a student will be judged on the selection and formulation of the propositions as well as on the defense of them. Formulating a set of propositions should begin early in the course of graduate study.

To emphasize the importance of these propositions, there will be a separate examination on the three propositions by the Ph.D. thesis committee. This examination on the propositions is normally taken after the thesis research progress meeting, but not less than 10 weeks in advance of the final doctoral examination. A copy of the propositions, along with suitable abstracts, must be submitted to the examining committee and to the division graduate secretary not less than two weeks before the propositions examination. These propositions must be acceptable to the committee before the final doctoral examination can be scheduled.

A copy of the thesis must be submitted to each member of the thesis committee not less than two weeks before the final doctoral examination. A copy of the thesis should also be submitted to the Graduate Office for proofreading three weeks prior to the final doctoral examination. One reproduced copy of the thesis, corrected after proofreading, is to be submitted to the division graduate secretary for the divisional library. Two final copies (one on Permalife paper) are to be submitted to the Graduate Office.

### *Subject Minor*

Graduate students in other options taking chemistry as a subject minor will be assigned a faculty adviser in chemistry by the Chemistry Graduate Study Committee. In consultation with this adviser, the student will work out an integrated program of courses, including at least 45 units of formal course work at the 100 level or above. This program must be approved by the Chemistry Graduate Study Committee, and a grade point average of 3.0 in the approved program will be required.

## **Civil Engineering**

### *Aim and Scope of the Graduate Program*

Civil Engineering (CE) research and study are offered through the Department of Mechanical and Civil Engineering (MCE). The degrees of Doctor of Philosophy (Ph.D.) and Master of Science (M.S.) are offered. The M.S. degree is normally only awarded to students who expect to pursue the Ph.D. degree in civil engineering and who do not already have an M.S. degree in civil engineering. In general, students who intend to work full-time toward the Ph.D. degree as a final degree objective are admitted to the civil engineering graduate program.

The aim of the graduate program in civil engineering at Caltech is to prepare students for research and professional practice in an era of rapidly advancing interdisciplinary technology. The program combines individual depth of experience and competence in a particular chosen major specialty, with a strong background in the basic and engineering sciences. It strives to develop professional independence, creativity, leadership, and the capacity for continuing professional and intellectual growth.

### *Preparation for the Graduate Program*

Students who have not specialized in civil engineering as undergraduates, as well as those who have, may be admitted for graduate study. As preparation for advanced study and research, entering graduate students are expected to have a thorough background in undergraduate mathematics, physics, and engineering. An outstanding four-year undergraduate program in mathematics and sciences may provide a suitable background as well. The qualifications of each applicant will be considered individually, and, after being enrolled, the student will arrange his or her program in consultation with a member of the faculty.