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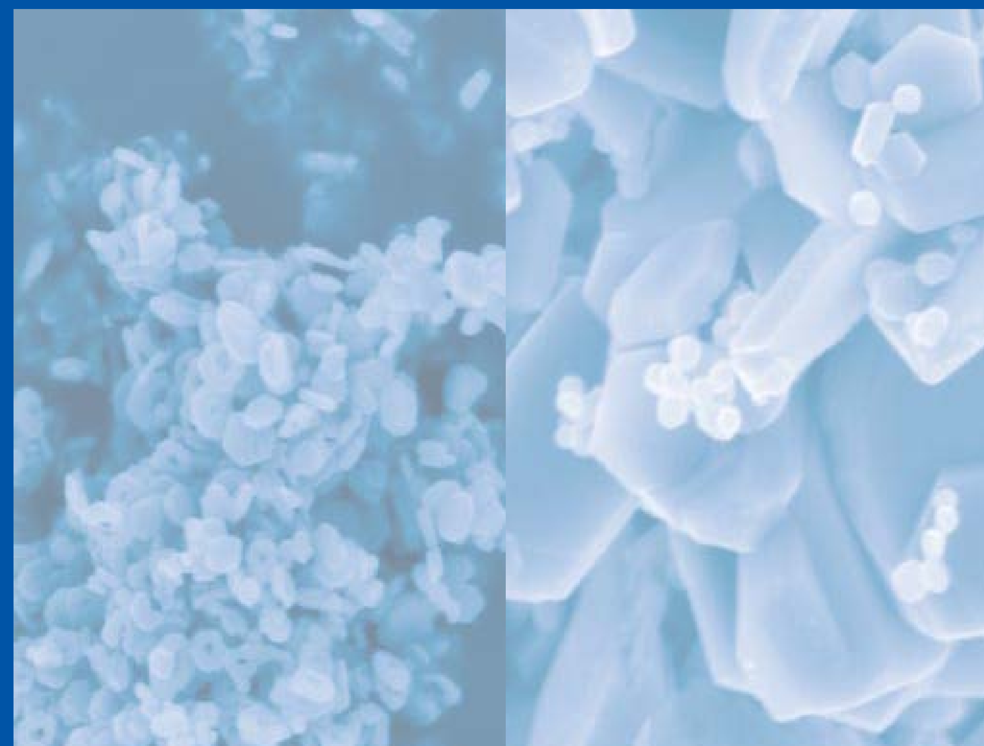
# ACS Guidelines for Chemistry in Two-Year College Programs



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# ACS GUIDELINES FOR CHEMISTRY IN TWO-YEAR COLLEGE PROGRAMS

## 1. Goals of the Guidelines

Chemistry is central to intellectual and technological advances in many areas of science. The traditional boundaries among chemistry subdisciplines are blurring, and chemistry is increasingly intersecting with other sciences. Unchanged, however, is the atomic and molecular perspective that lies at the heart of chemistry. Chemistry programs have the responsibility to communicate this outlook to their students and to teach the skills their students need to apply it.

Within the context of the diversity of institutions and students that make up American higher education, ACS has developed a set of guidelines to promote high-quality chemistry education for students in two-year college programs. The goal of these guidelines is to help faculty provide students with the best possible education in the fundamental areas of modern chemistry while relating it to other disciplines and to society.

ACS recognizes that diversity of institutions and students is a strength in higher education. Thus, the ACS guidelines for chemistry in two-year colleges have always provided a comprehensive model designed for a range of institutions.[1] Although a program may not fulfill all of the guidelines, it will benefit from pursuing those appropriate for its mission, student body, and curriculum. Implementing the guidelines can ensure that the chemistry course offerings and programs of an institution:

- are consistent with the mission of the institution,
- meet the needs of the diverse backgrounds and abilities of entering students,
- enhance the strengths of the institution and the community,
- articulate with programs to which students transfer,
- are comparable to programs of recognized quality, and
- augment continuing education and other local community chemistry education needs.

1 Those institutions that offer two-year programs in chemistry-based technology should also refer to the ACS Chemical Technology Program Approval Service.

Educators must prepare students to make informed decisions about a wide variety of scientific issues. These guidelines apply not only to students pursuing careers in scientific fields, but also to those in other areas.

These guidelines provide a framework for reviewing two-year college chemistry programs, for identifying areas of strength and opportunities for change, and for leveraging support from institutions, partners, and external agencies. In preparing and disseminating these guidelines, ACS seeks to enhance understanding of the many different two-year college environments, engaging chemistry faculty and programs across higher education in efforts to address needs, develop resources, and foster excellence.

## 2. Institutional Environment

To be effective, chemistry education requires an institutional commitment to student learning and success. Existing within the context of the institutional mission, chemistry in a two-year college program must support the needs, career goals, and interests of the institution's students.

In order to support a viable and sustainable chemistry program, the institutional environment must provide and develop the following attributes.

**2.1 Institutional Accreditation.** The institution must be accredited by the regional accrediting body. Such accreditation ensures broad institutional support in areas such as mathematics, related sciences, and the humanities. When undergoing institutional reviews, these guidelines should be consulted as part of self-studies and shared with the accrediting bodies.

**2.2 Faculty Policies.** The institution must support faculty efforts to develop high-quality instructional programs. The institution's policies regarding salaries, teaching loads, promotions, tenure and/or continuing contracts, leave policies (sabbatical or other), and hiring practices must be developed with faculty input, encourage improved faculty morale, and serve to attract and retain high-quality chemistry faculty members. Recognition programs should be in place to foster and reward significant contributions and innovations by the faculty and by individual faculty members.



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**2.3 Program Organization.** The administration of the program must rest in an appropriate department that includes full-time faculty members with chemistry degrees. The department must have an adequate budget and significant influence over faculty selection and promotion, curriculum development, and assignment of teaching responsibilities. Departmental input regarding allotment of office, classroom, laboratory, and other spaces must be solicited. If part of a larger unit, the chemistry faculty must have substantive autonomy over the functions relating to the chemistry courses.

**2.4 Program Budget.** A chemistry program requires continuing and stable financial support. The institution must have the ability and desire to make a sustained commitment to the program at a level that is consistent with the resources of the institution and its educational mission. Adequate support enables a program to provide:

- a qualified faculty with the scientific breadth to offer the courses and educational experiences described in these guidelines;
- nonacademic staff and resources for administrative support services, stockroom operation, and instrument and equipment maintenance;
- a physical plant that meets modern safety standards with appropriate chemical storage, waste-handling, and disposal facilities;
- sufficient budgets to cover the costs of teaching a laboratory-based discipline;
- resources for capital equipment acquisition, long-term maintenance, and expendable supplies to ensure that equipment remains useful throughout its lifetime;
- support for maintaining and updating instructional technology;
- modern chemical information resources appropriate for the breadth and depth of courses offered;
- services to support student learning;
- opportunities for professional development for the faculty, including sabbatical leaves;
- funds and support to encourage faculty members to attend professional meetings and promote scholarly growth;
- resources to support faculty-mentored research as appropriate to the institutional mission; and

- personnel support to assist with the acquisition and administration of external funding.

**2.5 Student Support Services.** An institution must have support services in place to help students move toward attaining their goals. Student support services must be appropriate for the student body and be consistent with the institutional mission. Support services should include:

- advising staff who work with the faculty to enable students to achieve their academic goals;
- staff specialized in helping students with career and transfer resources;
- academic and personal support for students with physical, communication, learning, and other disabilities;
- tutorial services for students to improve their study skills and become more effective learners;
- open and reliable access to technology, such as computers;
- programs and organizations to support and engage targeted communities of students, such as student clubs;
- programs that increase the participation of underrepresented groups; and
- assistance for students in acquiring financial aid.

## 3. Faculty and Staff

Providing a current and effective chemistry program requires an energetic and accomplished faculty. The chemistry faculty must be responsible for defining the overall goals of the program, facilitating student learning of content knowledge, developing students' professional skills, and modernizing the program as the discipline evolves. Mechanisms must be in place to maintain the professional competence of faculty members, to provide faculty development and mentoring, and to allow for regular feedback regarding faculty performance. Similar mechanisms are needed for instructional and support staff.

**3.1 Faculty.** The chemistry faculty should have the range of educational backgrounds, the expertise, and the commitment to provide a sustainable, robust, and engaging environment for student learning. Everyone who teaches chemistry courses that result in a grade on a





college transcript from the institution, regardless of location or mode of delivery, is considered part of the chemistry faculty and must meet institutional standards.

The program should have the following attributes:

- The minimum academic preparation required of any chemistry faculty member is a master's degree in a discipline of chemistry. The ability to communicate an understanding and appreciation of chemistry to others is essential. Further academic training (a doctoral or second master's degree in a related field) is highly desirable, particularly if it stresses depth and breadth of knowledge in chemistry.
- Full-time, permanent faculty should be sufficient in number to teach the full range of courses on a regular basis, with the number of credit hours taught by permanent faculty exceeding 75% of the total chemistry offerings.
- Qualified individuals outside the full-time, permanent faculty (i.e., contingent faculty)[2] should only be used to provide specific expertise and accommodate term-to-term fluctuations in enrollment. Excessive reliance on contingent faculty is strongly discouraged. When hired, such faculty should be fairly compensated, given equivalent facilities and professional development opportunities to those of full-time, permanent faculty, and integrated into the program's activities.
- The collective expertise of the faculty should reflect the breadth of the major areas of modern chemistry. If an institution has a mission that more narrowly defines its programs, the faculty expertise may reflect that focus.
- The department's climate and institutional policies should foster the development of a faculty with a wide range of backgrounds and experiences who can serve as role models for student bodies diverse in gender, ethnicity, race, and disability.

The ACS *Academic Professional Guidelines,* which describe responsibilities of students, faculty, and administration, should be followed. The institution should also comply with the *1940 Statement of Principles on Academic Freedom and Tenure.*[3]

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2 Contingent faculty are often referred to as adjunct, part-time, or nonpermanent faculty.

3 "The 1940 Statement of Principles on Academic Freedom and Tenure." *Law and Contemporary Problems 53, no. 5 (Summer 1990).*

**3.2 Teaching Contact Hours.** Contact hours are the actual time spent in the direct supervision of students in a classroom and/or laboratory. When determining faculty teaching assignments, each laboratory contact hour should be equivalent to a classroom contact hour. The number of contact hours in classroom and in laboratory instruction for faculty or instructional staff members *should not exceed 15 total hours per week.* Additionally, an instructor should carry no more than 450 student contact hours (i.e., the number of students multiplied by the number of contact hours) per week. Teaching assignments that exceed this standard risk lowering the quality of the chemistry program and the academic institution. Fifteen contact hours is an upper limit; a smaller number should be the normal teaching obligation. Faculty and instructional staff members in the most effective programs usually have substantially fewer contact hours, particularly when they supervise student research projects or assume administrative or support activities.

Faculty members, after fulfilling teaching obligations, must have adequate time for the following professional activities:

- holding office hours to meet with students;
- fulfilling service responsibilities to the department, the campus, and the community;
- developing new courses and curriculum innovations;
- assessing and improving curriculum;
- keeping abreast of new developments in chemistry and new educational pedagogies;
- participating in professional activities including conferences; and
- engaging in scholarship in chemistry, chemistry education, and teaching effectiveness.

No faculty member should be responsible for more than 25 students in a laboratory at one time.[4] Many laboratories require smaller numbers for safe and effective instruction (e.g., 20 students is the recommended maximum for an organic chemistry laboratory).

**3.3 Professional Development.** Sound policies regarding salaries, duties, promotions, sabbatical leaves, and tenure are essential. Institutional policies and practices should provide opportunities and

4 *Safety in Academic Chemistry Laboratories, Vol. 2, Accident Prevention for Faculty and Administrators,* 7th Edition. American Chemical Society: Washington, DC; 2003.





resources for scholarly activities, which allow faculty and instructional staff members to stay current in their specialties and in modern pedagogy in order to teach effectively.

- The institution should provide opportunities and funding for renewal and professional development through sabbaticals, participation in professional meetings, and other professional activities. Faculty and instructional staff members should use these opportunities. Institutions should provide resources to ensure program continuity during sabbaticals and other leaves.
- The institution should offer mechanisms by which faculty members are mentored. Proper mentoring integrates all members of the instructional staff into the culture of their particular academic unit, their institution, and the chemistry profession, ensuring the stability and vitality of the program.

In addition to supporting scholarly activities, the institution should provide regular training in the areas of safety, technology, and assessment.

**3.4 Support Staff.** A sustainable and robust program requires an adequate number of secretarial, administrative, and support personnel, along with technical staff to maintain instrumentation, support laboratory functions, and assure regulatory and safety compliance. The number of support staff members should be sufficient to allow faculty members to devote their time and effort to academic responsibilities and scholarly activities. One full-time laboratory technician for every four full-time or full-time-equivalent chemistry faculty members is needed. Part-time and student help are not adequate substitutes for full-time laboratory technicians.

To foster the development of a safe environment and a safety-conscious culture, all technical staff members, including part-time and student help, should receive regular training in chemical safety protocols, proper use of equipment, and waste management.

## 4. Infrastructure

A modern infrastructure is essential for an effective and rigorous chemistry program. Institutional support for program infrastructure is needed for sustainability through inevitable fluctuations in faculty, leadership, and funding levels.

**4.1 Organization of Facilities.** A program must have appropriate classroom, laboratory, other instructional, office, and common space that is safe, well-equipped, modern, and properly maintained. Laboratory and stockroom space must conform to applicable government standards and regulations.

- Chemistry classrooms should be reasonably close to instructional and research laboratories. Classrooms should adhere to modern standards for lighting, ventilation, and comfort and have proper demonstration facilities, projection capabilities, and Internet access. Classrooms should also be flexible learning spaces that are able to accommodate new pedagogies.
- Faculty offices should be configured for instructional and other professional activities. They should also accommodate confidential discussions with students and colleagues. Offices should have networked computers that provide access to library resources. Faculty offices should be reasonably close to teaching and laboratory facilities and positioned to facilitate student contact. Contingent faculty members should have comparable offices.
- Laboratories must have properly functioning utilities, fume hoods, safety showers, eyewashes, first aid kits, and fire extinguishers.
- Laboratory capacities should not exceed 25 students.[5] At least 50 square feet of net space per student should be provided, including lab tables and benches.
- Laboratory facilities must be able to accommodate students with disabilities in accordance with federal and state regulations.
- A properly maintained chemical stockroom should be in the vicinity of teaching and research space. The stockroom must provide safe storage, handling, and preparation areas and permit easy distribution of chemicals to required areas.
- Laboratories should have facilities appropriate for the type of work conducted in them. These facilities should permit maintaining experimental arrangements for extended periods of time during ongoing research projects.

**4.2 Equipment and Instrumentation.** Programs should have a suite of modern chemical instrumentation and specialized laboratory apparatus

5 NFPA 101, *Life Safety Code*, 2006 Edition; National Fire Protection Association: Quincy, MA, 2005.



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appropriate for the courses offered, providing hands-on laboratory experiences in synthesis, characterization, and analysis.

- Programs must have certain essential equipment, such as electronic balances, volumetric glassware, pH meters, colorimeters, thermometers or temperature probes, hot plates and/or Bunsen burners, and filtration equipment.
- Standard items, such as automated data-collection devices with associated probes, bench-top centrifuges, melting point apparatus, microscale or full-scale organic kits, gas chromatographs, and UV-Vis spectrometers, are highly recommended for programs serving students pursuing careers in science or health.
- Students pursuing chemistry careers should have access to instrumentation such as FTIR, FT-NMR, and mass spectrometers, if not at the institution, at other locations.

Chemical instrumentation is an evolving area of chemistry. Faculty members should have opportunities to keep abreast of these changes and improve the program's instrumentation.

**4.3 Computational Capabilities and Software.** Students should have access to computing facilities and software that support laboratory data acquisition and analysis, interactive simulations, and computational chemistry. Software with scientific word processing and illustration capabilities should be available.

**4.4 Chemical Information Resources.** Both faculty and students should have access to the chemical literature. Physical and electronic repositories should include current chemistry and related science periodicals, plus a range of other reference materials, commensurate with the size and nature of the chemistry offerings and the scholarly activity of the students and faculty. Important reference materials, or electronic access to these materials, should be within or near the science building.

- The chemical literature continues to expand at a rapid rate. The library should provide access to journal articles that are not readily available on site by supplying other mechanisms, such as interlibrary loan, electronic transmission, or document delivery services.
- Instruction on the use of information from the chemical literature should be equivalent to that in the institutions to which students

commonly transfer. Trained science librarians should be involved in the design and facilitation of these activities.

**4.5 Chemical Safety Resources.** The program must be conducted in a safe environment with adherence to federal, state, and local regulations regarding chemical storage, hazardous waste management, and laboratory safety. This includes the following attributes:

- a written chemical hygiene plan and proper facilities and personnel for chemical waste disposal;
- safety information and reference materials, such as material safety data sheets (MSDSs), and personal protective equipment readily available to all students and faculty;
- a policy of maximum stockroom chemical holdings, including small quantities for especially hazardous materials;
- personnel designated to coordinate all aspects of the chemical safety program in cooperation with institutional and other departmental safety programs; and
- segregated storage areas designated for acids, bases, reducing agents, oxidizing agents, and toxic materials. Cabinets and refrigerators that store flammable materials must meet the federal and state Occupational Safety and Health Administration (OSHA) regulations. National Fire Protection Association (NFPA) labeling codes must be used on all reagents and storage facilities.

## 5. Curriculum

The chemistry curriculum must be driven by the needs of the students, the mission of the institution, and the standards of the discipline. Recognizing that these may change over time, the curriculum should reflect two specific areas of need: (1) students who require education in the scientific method but do not require a significant amount of science for their ultimate academic and career goals; and (2) students for whom chemistry will be a substantial part of their academic path. This latter group includes students in allied health and all other health science fields, as well as those in science, technology, and engineering. Education majors may fall into either group, as appropriate for local certification.



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**5.1 Pedagogy.** Sound pedagogy informed by research on student learning is the cornerstone of an effective chemistry curriculum. The institution must regularly review its chemistry program to ensure that it provides excellent content with good pedagogy and builds skills that students need to be valuable professionals.

As an experimental science, chemistry must be taught using appropriate and substantial laboratory work that provides opportunities for open-ended investigations, which promote independent thinking, critical thinking and reasoning, and a perspective of chemistry as a scientific process of discovery. Courses should be taught in a challenging, engaging, and inclusive manner that accommodates a variety of learning styles.

Faculty members must be provided with opportunities to maintain their knowledge of best practices in chemistry pedagogy and modern theories of learning and cognition. Current examples of effective pedagogy include problem- or inquiry-based learning, peer-led instruction, group learning, learning communities or networks, writing throughout the curriculum, and technology-aided instruction.

**5.2 Prerequisites.** The diversity in the educational background, learning readiness, academic ability, and educational goals of students must be considered in curriculum development. The institution must accept that all students are not prepared to begin chemistry at the same level and that all programs requiring chemistry do not cover identical topics. The prerequisites for each chemistry course should be carefully determined, in consultation with colleagues at other institutions if appropriate, and assessed by the faculty. Prerequisites should be clearly stated and publicized in the college catalogues, in the schedule of classes, and in any other curriculum publications.

Students are best served when everyone involved in admitting students to chemistry classes respects the importance of adhering to prerequisites. Failure to do so reduces student retention and graduation rates, as well as the quality of the learning environment. An effective assessment of each student's preparation and readiness for a course can be achieved by testing, transcript evaluation, and/or counseling. Students who do not have the prerequisites for a given chemistry course should be redirected to the necessary preparatory course(s) in chemistry, mathematics, and/or other developmental skills.

**5.3 Consistency of Course Offerings.** Content and learning outcomes of a course should be monitored to ensure a consistent level of academic rigor. All sections of a course that result in a grade on an official transcript from the institution, regardless of location or mode of delivery, must be taught by qualified faculty members and use course materials with similar coverage and levels of difficulty.

**5.4 General Education Chemistry Courses.** General education chemistry courses should be transferable and include a laboratory component that satisfies the science requirement for graduation. The mathematical requirement is usually elementary algebra. The goal of such courses should be to educate students in the process of science, the atomic and molecular perspective of matter, and chemistry's relationship to other sciences, technology, and society. Such courses may be interdisciplinary.

**5.5 Preparatory Chemistry Courses.** Students may need chemistry courses to prepare them for college-level programs of study. Such courses emphasize concepts, critical thinking, and chemical calculations required to be successful in chemistry and should include a laboratory component equivalent to that in a high school chemistry course.

**5.6 Specialty Chemistry Courses.** Focused programs of study, such as those for primary and secondary educators, emergency first responders, and medical technicians, may require specialty chemistry courses. The curricula for such programs should be developed in close consultation with the appropriate professional or academic body for which the course is developed. The content of specialty chemistry courses, being directly relevant to the careers of its students, should, at a minimum, be taught at the level of preparatory chemistry courses (Section 5.5). The laboratory component should concretely demonstrate the application of chemistry within the specialty field.

**5.7 Chemistry for Allied Health and Health Sciences.** Chemistry courses required for students in allied health and health science programs should be developed in consultation with the programs in which



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the students are enrolled and to which they will transfer. The laboratory component should concretely demonstrate the application of chemistry within the health sciences. Prerequisites should be specified.

**5.8 General Chemistry.** Traditionally, general chemistry is a first-year college course sequence designed for science majors and students who aspire to become professional chemists. Completion of general chemistry course work ensures a common background in basic chemical concepts such as stoichiometry, states of matter, atomic structure, molecular structure and bonding, thermochemistry, equilibria, and kinetics. Course work must include a laboratory component.

Common outcomes of general chemistry should include knowledge of basic chemical concepts, strength in quantitative problem solving, preparation for higher-level course work, maturation of students' knowledge of chemistry, and application of mathematical skills. Students also need to be competent in basic laboratory skills, including laboratory safety, keeping a notebook, use of electronic balances and volumetric glassware, preparation of solutions, chemical measurements using pH electrodes and spectrophotometers, data analysis, and report writing. The diversity of institutions and students requires a wide variety of approaches to optimize the progress of students.

The prerequisites for general chemistry are typically the equivalent of one year of high school chemistry with a laboratory component and three years of high school mathematics, including two years of algebra. For students whose preparation is deficient, successful completion of a preparatory chemistry course, or its equivalent, as well as the necessary mathematics courses, should be required.

**5.9 Organic Chemistry.** Traditionally, organic chemistry is a second-year course sequence designed for science majors and students who aspire to become professional chemists. Articulation of organic chemistry course work, including the laboratory, should be established with institutions to which students transfer. Typically, the equivalent of two semesters of general chemistry with laboratory is a prerequisite for organic chemistry.

**5.10 Laboratory Experience.** To learn chemistry, students must directly manipulate chemicals, study their properties and reactions, and use laboratory equipment and modern laboratory instruments. Laboratory work in chemistry courses must be designed to give students an understanding that experimental work is the foundation of chemical knowledge. This hands-on experience is necessary for students to understand, appreciate, and apply chemical concepts. It should also develop student competence and confidence. Depending on the level and nature of the course, laboratory experiences should include the following activities:

- anticipating, recognizing, and responding properly to potential hazards in laboratory procedures;
- keeping accurate and complete experimental records;
- performing accurate quantitative measurements;
- interpreting experimental results and drawing reasonable conclusions;
- analyzing data statistically, assessing the reliability of experimental results, and discussing the sources of systematic and random error in experiments;
- communicating effectively through oral and written reports;
- planning and executing experiments through the use of appropriate chemical literature and electronic resources; and
- synthesizing and characterizing inorganic and organic compounds.

Computer simulations that mimic laboratory procedures have the potential to be useful supplements, but should not be considered equivalent replacements for hands-on experiences critical to chemistry courses at any level.

**5.11 Frequency of Course Offerings.** The institution should schedule courses so students can complete a full sequence of general or organic chemistry in a single academic year, or both general and organic sequences in two academic years. An annual listing of chemistry courses should be published and widely distributed, permitting students to schedule courses in proper sequence. The schedule of chemistry courses should be coordinated with the schedule of the other required courses within common degree tracks. Ideally, the lecture and laboratory components of a course are taken concurrently.

**5.12 Transfer Students.** Faculty, counselors, and advisers from two-year chemistry programs should be in regular communication with their





counterparts at institutions that accept a significant number of transfer students in order to ensure that the curricula of both institutions are appropriately coordinated. Two-year programs should convey the educational backgrounds and academic goals of their students to the receiving institutions. Both transferring and receiving institutions should assist students in making a successful transition.

Although specific courses are most commonly articulated by two-year and four-year institutions, it is recommended that program articulation be used to better serve students. Transferring students should be counseled to take the full general chemistry course sequence, full organic chemistry course sequence (if appropriate), cognate mathematics and physics courses, and general education courses in patterns comparable to the course work of freshmen and sophomores at the institutions to which the students plan to transfer.

## 6. Student Research and Scholarly Activities

Engaging two-year college students in original research and other scholarly activities has many benefits. It allows students and faculty members to integrate and reinforce chemistry knowledge, develop their scientific and professional skills, create new scientific knowledge, and add new contributions to other knowledge bases. It fosters interactions among students and faculty members and enhances student interest in science. Research activities are also effective in keeping faculty members current in chemistry fields and in a position to enrich contemporaneous course content. Such activities help students, faculty members, and administrators develop an understanding and appreciation of the importance of scientific research in maintaining American competitiveness in the global workforce. In addition, experimental work can provide a basis and rationale for acquiring modern instrumentation.

Student-centered research projects can be pursued independently or integrated into the curriculum. Projects can be conducted on campus, in the facilities of partnering institutions, or in other scientific facilities. Developing group or interdisciplinary projects can help broaden the applicability and relevance of chemistry in allied fields.

A suitable project:

- is well-defined with clear goals and objectives,
- stands a reasonable chance of completion in the available time,

- applies and develops an understanding of in-depth concepts,
- uses a variety of methods and instrumentation, and
- is grounded in the chemical literature.

Implementing a student-centered research program requires resources, including faculty time, laboratory space, instrumentation, chemical literature, supplies, and student stipends. The investment is justified by its impact on student learning and the richness it adds to students' and faculty members' scientific experiences.

## 7. Development of Student Skills

Although formal course work provides students with an education in chemical concepts and training in laboratory practices, students should go beyond course content alone to be effective and productive scientists. They need to master a variety of lifelong skills that will allow them to become successful professionals.

In addition to providing students with an education in chemical concepts, training in laboratory practices, and opportunities for critical thinking, programs should help students be effective and productive professionals. Strategies for helping students develop ethical behaviors and skill sets needed for successful careers include offering courses dedicated to skills and ethics, integrating activities into regular curricular offerings, and engaging students in research experiences. Regardless of the approaches used, programs should also assess the development of student skills.

**7.1 Problem-Solving Skills.** Chemistry education should provide students with the tools to solve problems. Students should be able to define problems clearly, develop testable hypotheses, design and execute appropriate experiments, analyze data, and draw appropriate conclusions. Students should use appropriate laboratory skills and instrumentation to solve problems while understanding the fundamental uncertainties in experimental measurements.

**7.2 Chemical Literature Skills.** Students going beyond general chemistry should be able to use the peer-reviewed scientific literature effectively and evaluate technical articles critically. They should learn how to retrieve specific information from the chemical literature, including





*Chemical Abstracts* and other compilations, with online, interactive database-searching tools.

**7.3 Laboratory Safety Skills.** Programs should promote a safety-conscious culture in which students understand the concepts of safe laboratory practices and apply them at all times. Programs should train students in the aspects of modern chemical safety appropriate to their educational level and scientific needs. A high degree of safety awareness should begin during the first laboratory course, and both classroom and laboratory discussions must stress safe practices. Students should understand responsible disposal techniques, understand and comply with safety regulations, understand and use material safety data sheets (MSDSs), recognize and minimize potential chemical and physical hazards in the laboratory, and know how to handle laboratory emergencies effectively.

**7.4 Communication Skills.** Effective communication is vital in all careers. Since speech and English composition courses alone rarely give students sufficient experience in oral and written communication of technical information, the chemistry curriculum should include writing and speaking opportunities, and the chemistry faculty should evaluate them critically. Students should be able to present information in a clear and organized manner, create visual representations of complex data sets, write well-organized and concise scientific reports, cite sources properly, and use appropriate technology, such as poster preparation software, word-processing software, chemical structure drawing programs, and computerized presentations.

**7.5 Team Skills.** Solving problems often involves working in teams. Students should be able to work effectively in groups, as leaders or team members, to solve problems and interact productively with a diverse group of peers. The faculty should incorporate well-structured team experiences in classroom and laboratory components of the chemistry curriculum.

**7.6 Ethics.** Ethics should be an intentional part of the instruction in chemistry programs. Students should conduct themselves responsibly and be aware of the role of chemistry in contemporary societal and global issues. As role models, faculty and staff members must exemplify ethics in their scholarship and professional conduct.

## 8. Student Mentoring and Advising

Effective mentoring and advising fosters student success and must be an integral part of the institutional environment. Academic advisers, counselors, and faculty members should help students develop educational goals and guide their professional development via networking opportunities, confidence building, and career planning. A strong collaboration among the chemistry faculty, counselors, and advisers at the institution and their contacts at local high schools, receiving institutions, and industries should be fostered and sustained in order to increase students' matriculation, transfer, job placement, and achievement of career goals.

Programs should provide information about combining a basic chemistry education with studies in other disciplines. For example, a major in chemistry with supporting work in biology is good preparation for students planning careers in medicine, dentistry, or pharmacy. In addition, many careers in the chemical industry, government, and other areas are open to graduates who have a solid background in chemistry combined with computer science, law, economics, environmental science, library science, history, literature, or philosophy.

**8.1 Faculty Advisers and Mentors.** Given their regular interaction with students, faculty members can be particularly effective advisers and mentors. Faculty members should encourage students to consider the career options available within chemistry. Student-centered research, which provides exceptional mentoring opportunities, can be an enriching experience for faculty members as well. Faculty members serving as advisers or participating in formal advising programs should be compensated or given reassigned time.

**8.2 Counselors and Advisers.** Counselors and advisers should be familiar with the career opportunities for students in transfer programs, along with the academic preparation necessary for entry into various chemistry courses. They should encourage students with strong interests and abilities in chemistry to continue their education in the chemical sciences. Two-year colleges should use discipline-specific counselors





and advisers to promote familiarity with chemistry and chemistry-related programs and to facilitate articulation with four-year college programs and industry. Students anticipating transfer to a four-year degree program should be counseled to complete all terms of sequential courses (the general chemistry sequence and the organic chemistry sequence, if appropriate) as well as mathematics and other science sequences before transfer.

## 9. Program Self-Evaluation and Assessment

Self-evaluation should be an ongoing process leading to continual improvement of a program. A transparent and reflective self-evaluation process that collects, considers, and acts on evidence should produce prepared students, support ongoing professional development and scholarly activities of faculty members, and develop an infrastructure that strongly supports the educational mission of the program.

**9.1 Program Goals and Objectives.** Institutions must ensure that infrastructural support is consistent with program goals and objectives. The chemistry faculty should implement a variety of assessment techniques and tools, providing the necessary data for making informed decisions at the classroom, course, and program levels. These decisions should lead to the implementation of practices that effectively address the needs of the students.

**9.2 Teaching and Student Learning.** Assessment of teaching and student learning should be an integral part of the institutional mandate. Programs should have established procedures to regularly assess and evaluate their effectiveness with respect to curriculum and pedagogy. For example, the ACS Examinations Institute provides a wide variety of tests to assess student learning while providing national norms and statistics. Institutional research offices often have access to student data on preparedness, advancement through programs, and subsequent performance at four-year institutions. These offices should provide opportunities to survey students during and after enrollment.

**9.3 Innovations in Instruction.** Ongoing assessment and continuing instructional revision improves student learning and reinforces improvements in curriculum and pedagogy. Faculty members should be encouraged to seek professional development opportunities through teaching and learning centers and to develop new pedagogical initiatives. When new courses and pedagogical initiatives are developed, their effectiveness and value should be assessed. Innovation and experimentation in the educational process, coupled with a strong assessment component, should preserve the vitality of chemistry education.

## 10. Partnerships

Two-year college programs should enhance the impact and success of their activities through various partnerships. Regardless of whether the goal is to increase matriculation from secondary schools, facilitate transfer to other postsecondary institutions, foster scholarly activities, enhance student exploration of career opportunities, or advance other strategic objectives, programs should engage stakeholders in meaningful, ongoing dialogue that develops trust and mutually beneficial relations. Establishing clear responsibilities and regular communications should help leverage resources and expertise, positioning two-year college programs to respond to the changes occurring in education and the workforce.

**10.1 Campus Units.** The quality and success of chemistry programs is dependent upon interactions among campus units. Strong coordination and ongoing communication should occur among the chemistry faculty, staff providing support services, and counselors and advisers who help students with course placement, sequencing, transfer options, and career opportunities. By establishing collaborative activities, programs will leverage and increase the effectiveness of their efforts. Such activities may be supported by external funds.

Interactions among departments and disciplines should also be encouraged. The institution should provide opportunities for interdisciplinary discussions and collaborations among faculties, ensuring that students receive a well-rounded collegial perspective on chemistry.

**10.2 Higher Education Institutions.** Partnerships between two-year and other post-secondary programs take on many forms and have many benefits. Collaborative faculty projects and group meetings, articulation



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conferences and workshops for faculty, and undergraduate research are just a few examples. In addition to enriching students and faculty members, such partnerships foster student transfer, increase student retention, and enhance and expand program offerings.

Successful student transfer requires candid and ongoing conversations between faculties at two-year colleges and receiving institutions. This is particularly important when curricular changes are being made and when students enroll in and transfer to a number of different receiving institutions. The conversations should serve to align curricular content and allow for exchange of ideas in delivering effective instruction and developing new approaches to strengthening student success at both transfer and receiving institutions.

Two-year college chemistry programs choosing to match the first two years of an ACS-approved program in chemistry must be familiar with the current guidelines for bachelor's degree programs and the way in which the ACS-approved program has implemented them. Students wishing to obtain a bachelor's degree from an ACS-approved program, particularly a certified degree, should also consult with a representative from that program and refer to *Undergraduate Professional Education in Chemistry: ACS Guidelines and Evaluation Procedures for Bachelor's Degree Programs.*

Each institution involved should have a mechanism for coordinating and communicating to students, faculty, counselors, and advisers the terms of articulation agreements. Agreements that specifically describe the courses and learning outcomes for efficient transfer are the keys to student-centered advising.

Partnerships with other institutions of higher education can leverage resources, enhancing and expanding the offerings of two-year programs. If two or more institutions in the same geographical area are unable to offer a complete two-year chemistry program individually, the institutions should consider combining resources and facilities to provide a full two-year chemistry program. Institutions with programs in place can also benefit from cooperative agreements, gaining access to libraries, laboratory facilities, and sophisticated instrumentation on other campuses. Second-year and specialized occupational courses, in particular, can be improved by such partnerships. They can also make participation in research by faculty members and independent study students a reality.

**10.3 K–12 Institutions.** Partnerships with high schools that promote early enrollment in college or offer advanced standing for certain high school courses are valuable ways to recruit students and increase the number of enrollments of first-generation and other students who are not likely to matriculate directly into college. Any course offered at a secondary school that results in a grade appearing on a college transcript must be taught by an individual qualified to teach the comparable course at the college. Such an arrangement should involve close oversight, review, and assessment by the college chemistry faculty to ensure similar levels of academic rigor and consistent learning outcomes.

Partnerships with K–12 institutions can be very beneficial for programs preparing students for careers in teaching, providing professional development for in-service teachers, and preparing chemists to transition to careers in K–12 education.

**10.4 Nonacademic Institutions.** Two-year college programs can obtain scientific expertise and resources from nonacademic institutions. Cooperative agreements with industrial and government laboratories can provide access to libraries, laboratory facilities, and sophisticated instrumentation, enhancing the curricular offerings and research opportunities of two-year programs. Research positions and internships for faculty and students are also possible.

Nonacademic institutions can also assist with career development. Laboratories, museums, and workforce development agencies are among those institutions that can host field trips and serve as sources of speakers and potential role models and mentors for students. Interactions between faculty and employees of these institutions can provide valuable insights and information to be shared with students during chemistry courses and conversations about careers.

## Acknowledgments

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