Department of Chemistry

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Mission Statement

Chemistry at Carnegie Mellon University is committed to making advances in the molecular sciences with lasting impact on foundational knowledge while tackling critical global challenges including sustainability, health, and quality of life.

Chemistry is an area of science involved with the study of the properties and reactions of substances ranging from living cells to subatomic particles. It is at the center of many scientific and technical fields, providing the fundamental knowledge and tools needed to address many of society's needs and to explore the unknown. Fields as diverse as genetic engineering, materials science and nanotechnology look to chemistry when they look to the future, for that is where the ultimate in understanding — the molecular level — resides.

Flexible Career Options

The chemistry profession is extraordinarily diverse, with career opportunities available in the chemical, petroleum, renewable energy, nuclear power, novel polymeric materials, metals, personal care and pharmaceutical industries, among many others. Chemistry plays an increasingly important role in the rapidly expanding biomedical and biotechnology industries. In addition to careers in industry and academia, many chemists find rewarding careers in the public sector in the laboratories of the National Institutes of Health, the Food and Drug Administration, the Environmental Protection Agency, the National Institute of Standards and Technology, and the Department of Energy as well as in consulting. Chemistry graduates also find employment in technical fields unrelated to science but where their problem solving and communication skills are highly valued.

Chemistry is a particularly suitable major for pre-medical and other pre-health profession students. Medical schools look favorably on the rigorous reasoning skills chemists develop, as evidenced by an excellent record for student admission to advanced education in these areas. An increasing number of our graduates are seeking careers in dentistry, pharmacy or pharmacology in addition to medicine. The Health Professions Program advises all Carnegie Mellon students considering careers in health fields. (See Health Professions Program description in this catalog for more information.) Chemistry is also excellent preparation for careers in law, especially for those with an interest in specializing in patent, intellectual property or environmental law. The curriculum has the flexibility to allow these students to participate in the CMU Washington Semester Program with the possibility of an internship in science policy should they desire. Students interested in industrial careers often combine their chemistry program with undergraduate courses in business administration or eventually go on to study for an M.B.A.

Any graduating class in chemistry reflects this diversity in career paths. Some recent examples from the class of 2020 are alums working as software engineers for Bloomberg in London and at MasterCard, in Healthcare Technical Services at Epic Systems, as a Research Scientist at Eli Lilly and as a Clinical Research Assistant at Children's Hospital of Pittsburgh. Others are finishing an M.S. degree in Colloids, Polymers and Surfaces at Carnegie Mellon University and working with CityYear through Americorps while applying to law school. Many are attending PhD programs in areas like biomaterials, nuclear engineering, polymer science and chemistry at top institutions including Stanford, UC Berkeley, Yale and the University of Illinois at Urbana Champaign. Chemistry majors often comment with enthusiasm regarding the close-knit community, which includes the opportunity to network with alums through the Undergraduate Seminar program in chemistry.

Degree Pathways

The Department offers three Bachelor's degrees: the B.S. in Chemistry, The B.S. in Chemistry/Biological Chemistry Track and the B.A. in Chemistry. One third of the courses for the B.A. degree are free electives that may be taken in any of the departments of the University and therefore offers a high degree of flexibility. For the B.S. degrees, electives are often technical courses in chemistry or related fields of science, technology and engineering, such as biology, physics, mathematics, chemical, biomedical or materials science engineering or computer science, although they can be in other non-technical areas as well. It is possible to have all of the technical requirements completed after the junior year in the B.S. and B.A. degree programs, allowing students the flexibility to combine electives in the senior year into a focused program of specialization or to allow for additional breadth in their undergraduate experience. Students interested in graduate studies in chemistry may enroll in graduate courses. Those desiring immediate job placement may be interested in one or more of the formal options that supplement the chemistry B.S. degree. These are described in detail later in this section of the catalog. Carnegie Mellon has one of the strongest polymer science programs in the world and the undergraduate polymer science, materials chemistry or colloids, polymers and sciences options offer training that is particularly valuable for an industrial career. The Computational Chemistry option provides students with expertise in scientific computing that is highly sought after by employers in the pharmaceutical industry. Throughout the curriculum the use of computational tools is emphasized and students have access to state-of-the-art instrumentation in their courses and through undergraduate research as described below.

The overlap between the fields of chemistry and biological sciences continues to grow, with increased emphasis on synthetic chemicals that are used as probes or reporters of biological function and diagnostic and/or therapeutic agents. In addition, the application of sophisticated spectroscopic, structural and scanning probe/force methods on scales as low as single molecules is driving innovation and education at the chemistry/biology interface. Based on these trends the department offers the B.S. in Chemistry/Biological Chemistry Track to better prepare students for advanced studies and a job market that values knowledge and skills from both disciplines. A combination of advanced research-focused lecture course offerings and a novel laboratory course in bioorganic chemistry allows students to build the strong foundation typical of a successful chemistry major, while expanding out into applications of chemistry in the biological sciences. Students who complete the track will have been exposed to the latest research accomplishments and unanswered questions in biological chemistry while also gaining experience in experimental methods unique to research at this interface.

Honors Programs with Strong Research Focus

An honors program is offered for highly motivated undergraduates. It is designed primarily for students who wish to undertake a strong research-intensive program of study in contemporary chemistry. The program B.S. in Chemistry with Departmental Honors requires the completion of at least one graduate level course in chemistry, a research project, and the writing and defense of a bachelor's level honors thesis. An advanced track leading to the B.S. in Chemistry with Departmental Honors together with a Master of Science degree in chemistry involves completion of five graduate level courses and a more extensive thesis research project. This degree path is especially attractive to students who plan to pursue an industrial career. With enough advanced placement credit or by carrying heavier than usual course loads, students can complete the Honors/M.S. degree program in 8 semesters, with research during one to two summers. The majority of openings in the chemical industry presently are at the Bachelors and Masters degree levels.

Additional majors (double majors) are available with nearly all other departments in the university provided the student can fit the required courses into the schedule. Generally, all the requirements for both departments must be met for an additional major (except for some courses with similar content). Programs are also available that lead to the degree B.S. in Chemistry with a minor in another discipline. Requirements for most minor programs are described by individual departments in this catalog. However, it is recommended that students who are interested in pursuing a minor as part of their degree consult with the department involved for the current requirements and further guidance about scheduling. Dual degree programs are available in which students receive two separate undergraduate degrees from two different departments in the University. These require students to complete at least 90 units of work per additional degree in addition to the units required for the first degree and the core curriculum from both colleges if the programs are in different units. Several five-year programs have been developed to allow a Carnegie Mellon undergraduate student to earn both a B.S. in Chemistry and a Master of Science degree in fields such as Health Care Policy and Management, Materials Science Engineering, Colloids, Polymers and Surfaces or Biomedical Engineering.

Study Abroad

Study abroad programs are available for chemistry majors and programs of one to two semesters can generally be accommodated without delaying time to graduation beyond 8 semesters. One example of a formal exchange program is spending two semesters at École Polytechnique Féderále de Lausanne (EPFL) in Switzerland. Students can also study at the Carnegie Mellon campus in Qatar. Study abroad is encouraged by the chemistry department and can be arranged on an individual basis at universities throughout the world including Europe, Asia, Africa, New Zealand, and Australia during the academic year, the summer and winter or spring

breaks. Students interested in study abroad should consult with their academic advisor and the MCS Study Abroad Advisor in the Office of International Education.

Undergraduate Research Opportunities

One of the most attractive features of the Department of Chemistry is the opportunity for students to interact with prominent research scientists in entry-level as well as advanced courses and in research. Undergraduate laboratory instruction takes place in a state-of-the-art facility located in Doherty Hall. Participation in undergraduate research is encouraged and qualified students may begin projects as early as their first year through research shadowing experiences. Chemistry majors interested in beginning research should consult with the Director of Undergraduate Studies to begin the process of identifying a research mentor. Approximately 90 to 98% of the graduating chemistry majors during the past ten years have taken part in research either for pay or for credit as part of their undergraduate training. Chemistry majors have been very successful in obtaining Small Undergraduate Research Grants (SURG) and Summer Undergraduate Research Fellowships (SURF) from the University to help support their research projects. Several students each summer obtain iSURF support, International Summer Undergraduate Research Fellowships, to work with research collaborators abroad.

Faculty in the Department of Chemistry are leading the way in the use of computer-controlled instrumentation for synthesis and analysis of chemical compounds. In addition to automated science capabilities in individual labs, our faculty are engaged in the design and construction of the very first Academic Cloud Lab (https://cloudlab.cmu.edu/) that will be housed at Carnegie Mellon University and is scheduled to open in the spring of 2023. This facility will allow graduate and undergraduate researchers to design and run experiments remotely, with the work carried out by robots and trained technicians according to computer code written by the researchers. In addition to use in research, our faculty have developed experiments within existing courses and created stand-alone courses utilizing the Emerald Cloud Lab; this coursework will transition to the Carnegie Mellon facility once it is opened.

Program Outcomes

The faculty members of the Department of Chemistry have approved the following as a statement of our learning outcomes for recipients of an undergraduate degree in chemistry.

Upon graduation recipients of the BS or BA degree in Chemistry will:

Foundational knowledge/theory

- Have a firm foundation in the quantitative and computational thinking that underlies chemistry, including use of modern computational tools.
- Have a firm foundation in the theories and models that form the basis for reasoning about molecular systems.
- Understand how the different subdisciplines of chemistry relate to and complement one another.
- Be able to apply chemical reasoning across disciplines, such as biology, environmental science, materials science, nanotechnology, and engineering.

Practical/Experimental

- Understand that chemistry is fundamentally an experimental science, and be able to identify or create an appropriate model, formulate a hypothesis, choose an appropriate set of tools and techniques, and design an experiment that tests the hypothesis and analyze the results from that experiment drawing sound scientific conclusions from the results obtained.
- Be proficient in the use of both classical and modern tools for analysis of chemical systems.
- Be able to design and carry out synthesis of both organic and inorganic systems.
- Be able to use experience and knowledge gained through theoretical and practical design projects to conduct further research.
- Know and follow the proper procedures and regulations for safe handling and use of chemicals and chemical equipment.

Communication

- Be able to convey information, both orally and in writing, to a range of audience levels and for a variety of purposes.
- Understand how scientific information is shared between peers in modern science, including responsible conduct for acknowledging prior and current contributions.
- Be able to locate, identify, understand and critically evaluate the chemical literature.
- Develop the interpersonal skills to function cooperatively in a team setting.

Society and ethics

- Understand the opportunities and consequences of chemistry for the environment and society for both the short term and for long-term sustainability.
- Understand and apply ethics and values to all professional activities.

Professional development

- Develop an understanding of career opportunities both within and outside of chemistry, including through contacts with faculty, the career and professional development center and alumni.
- Be prepared to pursue a life and career that builds on their experiences at Carnegie Mellon to achieve their personal goals and to contribute positively to society.

B.S. in Chemistry (and requirements for additional major in chemistry)

The majority of undergraduate degrees awarded by the Department of Chemistry are Bachelor of Science degrees. This degree program provides the most appropriate preparation for further graduate study and for industrial positions in research and development or analytical chemistry. The curriculum provides a strong foundation in the fundamental areas of study in chemistry: organic, physical, inorganic and analytical chemistry, along with a rich set of research-focused, instrumentation intensive laboratory experiences aligned with those areas. Students interested in less technical areas of employment or graduate study in areas such as business, policy or law may find the Bachelor of Arts degree a more suitable alternative.

The suggested curriculum recommends that the required technical courses be completed at the earliest opportunity, however students have considerable flexibility to postpone these courses in favor of electives, allowing compatibility with the programs of other departments. In designing such programs for a minor or additional major with chemistry, students should note that certain required chemistry courses only are offered in specific semesters, not both. These include the Fall-only courses , 09-219 Modern Organic Chemistry, 09-321 Laboratory III: Molecular Design and Synthesis and 09-323 Bioorganic Chemistry Laboratory and 09-344 Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry as well as the Spring-only courses 09-331 Modern Analytical Instrumentation, 09-220 Modern Organic Chemistry II, 09-345 Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry and 09-348 Inorganic Chemistry. Also, in some cases, a course that is normally scheduled for the fall may be changed to a spring course (or the inverse) due to a departmental curriculum change or faculty availability.

Curriculum in B.S. in Chemistry and Requirements for an Additional Major in Chemistry

This catalog and the sample schedules presented are intended to be used by students in the first year class entering in the fall of 2023. Upperclass students should refer to the appropriate previous version of the catalog published during their first year for the requirements that are specific to them.

The technical breadth requirement of the MCS core curriculum requires a minimum of four technical courses outside of the student's primary major. Chemistry majors must at minimum take the following non-chemistry technical courses:

Technical Breadth Requirements		Units
33-121	Physics I for Science Students	12
33-122	Physics II for Biological Sciences & Chemistry Students	9
03-121	Modern Biology	9
or 03-231	Honors Biochemistry	
or 03-232	Biochemistry I	
15-110	Principles of Computing - or other approved programming course	10
or 15-112	Fundamentals of Programming and Computer Science	
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	

Students should complete this technical core as early as possible and preferably by the end of their fifth semester. AP credit cannot be used to

fulfill the technical breadth requirements for the core though AP classes can be used to fulfill prerequisites for chemistry classes.

The non-technical breadth requirements for MCS students includes Interpretation and Argument (76-101, 9 units), four courses with a minimum of 36 units from the arts, humanities or social sciences and a course of at least 9 units from an approved list in the category of Cultural/Global understanding, a course in the Science and Society category of at least 6 units, a total of five ENGAGE courses including three ENGAGE in Wellness courses, ENGAGE in Wellness: Looking Inward (38-230, 1 units), ENGAGE in Wellness: Looking Outward (38-330, 1 units) and ENGAGE in Wellness: Looking Forward (38-430, 1 units), as well as ENGAGE in Service (38-110, 1 units) and ENGAGE in the Arts (38-220, 2 units) plus EUREKA!: Discovery and Its Impact (38-101, 6 units) the MCS first-year seminar for a minimum of 72 units.

The Science and Society requirement as well as the ENGAGE courses must be finished **prior** to your final semester at CMU (no later than your penultimate semester). The Science and Society requirement can be fulfilled in numerous ways via MCS classes and other disciplinary courses that can also fulfill other requirements for your degree (but can NOT double count within the general education categories i.e. a course used to fulfill Science and Society cannot also fulfill your Cultural Analysis requirement or count towards your 36 units of non-technical electives). In the chemistry department courses currently approved to fulfill the Science and Society requirement that can also count as a chemistry elective are 09-510 Chemistry and Sustainability , 09-291 Environmental Systems on a Changing Planet with 09-381 Environmental Systems on a Changing Planet: Science & Engineering Addendum and 09-403 Hooked: The Chemical Basis of Drug Addiction. A more expanded listing will be maintained by the MCS Dean's Office (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/index.html (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/)).

For more information on allowed courses in the arts, humanities and social sciences and electives in the Cultural/Global Understanding category refer to the MCS section of this catalog.

The following are only meant to represent sample schedules. Students should always consult with their academic advisor to discuss an individualized plan to meet their academic goals.

Freshman Year

Fall		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
21-120	Differential and Integral Calculus	10
33-121	Physics I for Science Students	12
76-101	Interpretation and Argument	9
38-101	EUREKA!: Discovery and Its Impact	6
99-101	Computing @ Carnegie Mellon	3
		50

Students interested in majoring in chemistry who have a strong chemistry background, should enroll in 09-107 rather than 09-105. Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

There are some elective laboratory courses offered for MCS students in the first year. These include 03-117 Frontiers, Analysis, and Discovery in Biological Sciences or 09-115 Introduction to Undergraduate Research in Chemistry. The maximum units allowed during the first semester is 54; therefore, students wishing to take a lab should take an alternate technical course to Physics I such as 15-110 or 03-121 so that their unit total is lower.

Spring		Units
09-106	Modern Chemistry II Chemistry majors who place out of 09-106 can take 09-348 Inorganic Chemistry, 09-510 Chemistry and Sustainability as a chemistry elective or 09-116 a course that will allow you to shadow upperclass mentors in undergraduate research in chemistry. Chemistry majors who feel they are ready for an undergraduate research experience should meet with the Director of Undergraduate Studies. These opportunities are more prevalent in the summer after your first year or sophomore year.	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	
33-121	Physics I for Science Students	12
or 03-121	Modern Biology	
or 15-110	Principles of Computing	
xx-xxx	Arts, Humanities and Social Sciences Course 1	9
xx-xxx	Free Elective	9.0
		50

Sophomore Year

Fall		Units
09-201	Undergraduate Seminar I	1
09-219	Modern Organic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
33-122	Physics II for Biological Sciences & Chemistry Students Course is a prerequisite for 09-331, normally taken in the spring of the junior year	9
xx-xxx	Arts, Humanities and Social Sciences Course 2	9
		41

Spring		Units
09-202	Undergraduate Seminar II: Safety and Environmental Issues for Chemists	1
09-220	Modern Organic Chemistry II	10
09-222	Laboratory II: Organic Synthesis and Analysis	12
09-348	Inorganic Chemistry (Students wishing to pursue careers in the health professions or are pursuing the Biological Chemistry Track may wish to take biochemistry, 03-232, and delay inorganic until the junior or senior year spring semester)	10
38-230	ENGAGE in Wellness: Looking Inward	1
xx-xxx	Arts, Humanities and Social Sciences Course 3	9
		43

Reminder about Flexible Scheduling: Student feedback indicates that the junior year BS schedule can feel quite intense as you move into the more mathematical and physical chemistry oriented curriculum, especially if you are also engaged in undergraduate research. Remember that the senior year in chemistry is essentially open for free electives. You may use this flexibility to spread out your junior year requirements over four semesters rather than two; though you should be careful about moving too many courses to the senior year as that may create additional stress at a time when you are preparing to move forward from CMU. You should consult with your academic advisor to explore alternative schedules if you are interested.

Junior Year

Fall		Units
09-301	Undergraduate Seminar III	1
09-231	Mathematical Methods for Chemists Math methods is a co-requisite for 09-344 and a prerequisite for 09-345 (spring). If you move math methods to the fall of your senior year, you must also move 09-344, 09-345 and 09-322 to the senior year.	9
09-321	Laboratory III: Molecular Design and Synthesis This lab class is not a prerequisite for 09-322; it can be moved to the fall of your senior year without impacting the spring junior year courses.	12
or 09-323	Bioorganic Chemistry Laboratory	
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry Quantum is a prerequisite for Lab IV. If you move Quantum to the fall of the senior year, you must move Lab IV to the spring of the senior year. 09-344 is not a prerequisite for 09-345 (spring).	9
38-330	ENGAGE in Wellness: Looking Outward	1
xx-xxx	Arts, Humanities and Social Sciences Course 4	9
		41

Spring		Units
09-302	Undergraduate Seminar IV	1
09-322	Laboratory IV: Molecular Spectroscopy and Dynamics	12

09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry This course is a co-requisite of Lab IV. If you move it to the senior year, you must also move Lab IV.	9
09-331	Modern Analytical Instrumentation This course is a co-requisite of Lab IV. If you move it to the senior year, you must also move Lab IV.	9
xx-xxx	Cultural/Global Understanding Requirement	9
xx-xxx	Approved Science and Society elective. This course can be scheduled at any point during your studies but prior to your final semester..	6-9
		46-49

Senior Year

Fall		Units
09-401	Undergraduate Seminar V	1
09-xxx	Chemistry Elective (see notes on electives)	9
38-110	ENGAGE in Service	1
38-220	ENGAGE in the Arts	2
38-430	ENGAGE in Wellness: Looking Forward	1
xx-xxx	Free Electives	30
		44

Spring		Units
09-402	Undergraduate Seminar VI	3
09-xxx	Chemistry Elective (see notes on electives)	9
xx-xxx	Free Electives	27
		39

Distribution of Units for B.S. in Chemistry and Requirements for An Additional Major in Chemistry

Minimum Total Chemistry Units 160; See distribution below

Required Chemistry Courses*		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
09-106	Modern Chemistry II	10
09-219	Modern Organic Chemistry	10
09-220	Modern Organic Chemistry II	10
09-231	Mathematical Methods for Chemists	9
09-331	Modern Analytical Instrumentation	9
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	9
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	9
09-348	Inorganic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
09-222	Laboratory II: Organic Synthesis and Analysis	12
09-321	Laboratory III: Molecular Design and Synthesis	12
or 09-323	Bioorganic Chemistry Laboratory	
09-322	Laboratory IV: Molecular Spectroscopy and Dynamics	12
09-xxx	Chemistry Seminars	8
09-xxx	Chemistry Electives	18

* These, plus 33-121 Physics I for Science Students and 33-122 Physics II for Biological Sciences & Chemistry Students, are the required courses for students earning an additional major in chemistry.

Students who transfer into the department and have taken 09-217 Organic Chemistry I and/or 09-218 Organic Chemistry II, will be required to complete units of 09-435 Independent Study Chemistry, 1 unit per course, under the supervision of the instructor(s) for 09-219 and/or 09-220 in order to master the course content missed in this course sequence.

Students who transfer into the department and have taken 09-207 Techniques in Quantitative Analysis and/or 09-208 Techniques for Organic Synthesis and Analysis will be required to take a 3 unit transition course (09-215 Chemistry Tech I to Lab I Transition for 09-207 and/or 09-216 Chemistry Tech II to Lab II Transition for 09-208) to fulfill the major requirements for 09-221 and/or 09-222.

Chemistry courses required for the BS degree and the additional major in chemistry that are numbered 09-2xx or higher must be taken at Carnegie Mellon University. Exceptions must be requested of and approved by the Director of Undergraduate Studies. In general such requests will be approved only under unusual or extenuating circumstances.

Other Requirements	Units
Biology (Modern Biology or Biochemistry)	**9**
Computer Science	**10**
Mathematics	**20**
Physics	**21**
Interpretation and Argument	**9**
Arts, Humanities and Social Sciences Courses	**36**
Cultural/Global Understanding	**9**
EUREKA! (First-year seminar)	**6**
Science and Society requirement	**6**
ENGAGE in Service	**1**
ENGAGE in Wellness Courses (three courses)	**3**
ENGAGE in the Arts	**2**
Computing @ Carnegie Mellon	**3**
Free Electives	**65**
Minimum number of units required for the degree:	**360**

The above B.S. curriculum recommends a range of 41–50 units per semester to meet the minimum degree requirement of 360 units. Students are strongly encouraged to take extra elective courses (except in the first year) in whatever subjects they wish in order to enrich their backgrounds and enhance their educational experience.

Some students may need to earn more than 360 units to complete their degree. Usually this happens when students earn AP Credit for a course (for example 09-105) and then take a class with the same or similar content (take 09-105 at CMU or 09-107). You cannot count 20 units towards a 10-unit requirement so this student would need to earn 370 total units.

Notes on Electives

Chemistry Electives

A minimum of 18 units of chemical electives is required.

Chemical electives can be satisfied by 09-445 Undergraduate Research, or by most other chemistry courses 09-3xx or higher, undergraduate or graduate, for which the student has the necessary prerequisites, or by 03-231/03-232 Biochemistry I. Biochemistry also fulfills the Life Sciences requirement for the MCS technical breadth requirement. 09-435 Independent Study Chemistry, may only be used to fulfill this requirement with permission of the Director of Undergraduate Studies. Certain interdisciplinary courses (e.g. 39-xxx) relating to chemistry can also be used with permission by the Director of Undergraduate Studies. Chemistry electives are intended to enhance a student's technical knowledge in chemistry. Some chemistry courses are more interdisciplinary in nature and/or less technical in content. This applies to 09-510 Chemistry and Sustainability and 09-291 Environmental Systems on a Changing Planet plus 09-381 Environmental Systems on a Changing Planet: Science & Engineering Addendum. (Note: 09-291 without the addendum cannot count as a chemistry elective.) Only one of these two courses may be counted towards fulfillment of 18 units of chemistry electives.

The scheduling of these electives can vary and students should check with the department offering the course to see which courses are offered in any given year or semester and with the Director of Undergraduate Studies in the Department of Chemistry to ascertain whether the course is an acceptable chemistry elective.

Free Electives

Free electives are defined as including any course offered by Carnegie Mellon except those in science or engineering fields that are primarily intended for non-majors. A maximum of 9 units total of Physical Education, StuCo and/or ROTC courses combined can be counted as free elective units. The Chemistry Department does not require technical electives.

B.A. in Chemistry

The curriculum for the B.A. degree provides students with the opportunity to take a substantial number of elective and non-technical courses. Certain chemistry, math, and other technical courses required for the B.S. degree

are replaced by free electives, making this degree an ideal choice for those who wish to earn an additional major with one of the departments in the College of Humanities and Social Sciences, College of Fine Arts, or with the Business Administration program, though this is not a requirement. It is also attractive for students wishing to pursue careers in dentistry or pharmacy, career paths that require a broader preparation at the undergraduate level and hence more coursework outside of chemistry. Students may earn one or more of the options as described for B.S. degree candidates, providing they complete the courses listed.

The suggested curriculum recommends that the required technical courses be completed at the earliest opportunity, however students have considerable flexibility to postpone these courses in favor of electives, allowing compatibility with the programs of other departments. In designing such programs for a minor or additional major with chemistry, students should note that certain required chemistry courses only are offered in specific semesters, not both. These include the Fall-only courses , 09-219 Modern Organic Chemistry, 09-321 Laboratory III: Molecular Design and Synthesis and 09-323 Bioorganic Chemistry Laboratory and the Spring-only courses 09-331 Modern Analytical Instrumentation, 09-220 Modern Organic Chemistry II and 09-348 Inorganic Chemistry. Also, in some cases, a course that is normally scheduled for the fall may be changed to a spring course (or the inverse) due to a departmental curriculum change or faculty availability.

Curriculum

This catalog and the sample schedules presented are intended to be used by students in the first year class entering in the fall of 2023. Upperclass students should refer to the appropriate previous version of the catalog published during their first year for the requirements that are specific to them.

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33-122	Physics II for Biological Sciences & Chemistry Students	9
03-121	Modern Biology	9
or 03-231	Honors Biochemistry	
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15-110	Principles of Computing	10
or 15-112	Fundamentals of Programming and Computer Science	
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	

Students should complete this technical core as early as possible and preferably by the end of their fifth semester. AP credit cannot be used to fulfill the technical breadth requirements for the core though AP classes can be used to fulfill prerequisites for chemistry classes.

The non-technical breadth requirements for MCS students includes Interpretation and Argument (76-101, 9 units), four courses with a minimum of 36 units from the arts, humanities or social sciences and a course of at least 9 units from an approved list in the category of Cultural/Global understanding, a course in the Science and Society category, a total of five ENGAGE courses including three ENGAGE in Wellness courses, ENGAGE in Wellness: Looking Inward (38-230, 1 units), ENGAGE in Wellness: Looking Outward (38-330, 1 units) and ENGAGE in Wellness: Looking Forward (38-430, 1 units), as well as ENGAGE in Service (38-110, 1 units) and ENGAGE in the Arts (38-220, 2 units) plus EUREKA!: Discovery and Its Impact (38-101, 6 units) the MCS first-year seminar for a minimum of 72 units.

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For more information on allowed courses in the arts, humanities and social sciences and electives in the Cultural/Global Understanding category refer to the MCS section of this catalog.

The following are only meant to represent sample schedules. Students should always consult with their academic advisor to discuss an individualized plan to meet their academic goals.

First Year

Fall		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
21-120	Differential and Integral Calculus	10
33-121	Physics I for Science Students	12
76-101	Interpretation and Argument	9
38-101	EUREKA!: Discovery and Its Impact	6
99-101	Computing @ Carnegie Mellon	3
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Students interested in majoring in chemistry who have a strong chemistry background, should enroll in 09-107 rather than 09-105. Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

There are some elective laboratory courses offered for MCS students in the first year. These include 03-117 Frontiers, Analysis, and Discovery in Biological Sciences and 09-115 Introduction to Undergraduate Research in Chemistry. The maximum units allowed during the first semester is 54; therefore, students wishing to take a lab should take an alternate technical course to Physics I such as 15-110 or 03-121 so that their unit total is lower.

Spring		Units
09-106	Modern Chemistry II *	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	
15-110	Principles of Computing	10
or 33-121	Physics I for Science Students	
or 03-121	Modern Biology	
xx-xxx	Arts, Humanities and Social Sciences Course 1	9
xx-xxx	Free Elective	9
		48

* Chemistry majors who place out of 09-106 can take 09-348 Inorganic Chemistry, 09-510 Chemistry and Sustainability as a chemistry elective, or other courses yet to be announced. Chemistry majors who feel they are ready for an undergraduate research experience should meet with the Director of Undergraduate Studies. These opportunities are more prevalent in the summer after your first year or sophomore year.

Sophomore Year

Fall		Units
09-201	Undergraduate Seminar I	1
09-219	Modern Organic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
33-122	Physics II for Biological Sciences & Chemistry Students This course is required before graduation but need not be taken this semester.	9
xx-xxx	Arts, Humanities and Social Sciences Course 2	9
		41

Spring		Units
09-202	Undergraduate Seminar II: Safety and Environmental Issues for Chemists	1
09-220	Modern Organic Chemistry II	10
09-222	Laboratory II: Organic Synthesis and Analysis	12
38-230	ENGAGE in Wellness: Looking Inward	1
xx-xxx	Arts, Humanities and Social Sciences Course 3	9
xx-xxx	Free Elective	9
		42

Junior Year

Fall		Units
09-301	Undergraduate Seminar III	1
09-321	Laboratory III: Molecular Design and Synthesis	12
or 09-323	Bioorganic Chemistry Laboratory	
03-121	Modern Biology	9
or 15-110	Principles of Computing	
38-330	ENGAGE in Wellness: Looking Outward	1
xx-xxx	Arts, Humanities and Social Sciences Course 4	9
xx-xxx	Free Elective	9
		41

Spring		Units
09-302	Undergraduate Seminar IV	1
09-348	Inorganic Chemistry	10
09-331	Modern Analytical Instrumentation	9
xx-xxx	Cultural/Global Understanding Requirement	9
xx-xxx	Approved Science and Society elective. This course can be scheduled at any point during your studies but prior to your final semester.	6-9
xx-xxx	Free Elective	9
		44-47

Senior Year

Fall		Units
09-401	Undergraduate Seminar V	1
09-xxx	Chemistry Elective	9
38-430	ENGAGE in Wellness: Looking Forward	1
38-110	ENGAGE in Service	1
38-220	ENGAGE in the Arts	2
xx-xxx	Free Electives	28
		42

Spring		Units
09-402	Undergraduate Seminar VI	3
09-xxx	Chemistry Elective	9
xx-xxx	Free Electives	40
		52

Distribution of Units

Minimum Total Chemistry Units 121; See distribution below:

Required Chemistry Courses		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
09-106	Modern Chemistry II	10
09-219	Modern Organic Chemistry	10
09-220	Modern Organic Chemistry II	10
09-331	Modern Analytical Instrumentation	9
09-348	Inorganic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
09-222	Laboratory II: Organic Synthesis and Analysis	12
09-321	Laboratory III: Molecular Design and Synthesis	12
or 09-323	Bioorganic Chemistry Laboratory	
09-xxx	Chemistry Seminars	8
09-xxx	Chemistry Electives	18

09-322 Laboratory IV: Molecular Spectroscopy and Dynamics may be taken in lieu of 09-321 Laboratory III: Molecular Design and Synthesis or 09-323 Bioorganic Chemistry Laboratory. However the student must complete the necessary pre- and co-requisites of 09-231, 09-344,and 09-345. In this case 09-345 and 09-344 will count as chemistry electives towards the B.A. degree.

Students who transfer into the department and have taken 09-217 Organic Chemistry I, and/or 09-218 Organic Chemistry II, will be required to complete units of 09-435 Independent Study Chemistry, 1 unit per course, under the supervision of the instructor(s) for 09-219 and/or 09-220 in order to master the course content missed in this course sequence.

Students who transfer into the department and have taken 09-207 Techniques in Quantitative Analysis and/or 09-208 Techniques for Organic Synthesis and Analysis will be required to take a 3 unit transition course (09-215 Chemistry Tech I to Lab I Transition for 09-207 and/or 09-216 Chemistry Tech II to Lab II Transition for 09-208) to fulfill the major requirements for 09-221 and/or 09-222.

Chemistry courses required for the B.A. degree that are numbered 09-2xx or higher must be taken at Carnegie Mellon University. Exceptions must be requested of and approved by the Director of Undergraduate Studies. In general such requests will be approved only under unusual or extenuating circumstances.

Other Requirements	**Units**
Biology (either Modern Biology or Biochemistry)	**9**
Computer Science	**10**
Mathematics	**20**
Physics	**21**
Interpretation and Argument	**9**
Arts, Humanities and Social Sciences courses	**36**
Cultural/Global Understanding	**9**
EUREKA! (First year seminar)	**6**
Science and Society Elective	**6**
ENGAGE in Wellness (3 courses)	**3**
ENGAGE in Service	**1**
ENGAGE in the Arts	**2**
Computing @ Carnegie Mellon	**3**
Free Electives	**104**
Minimum number of units for the degree	**360**

The above B.A. curriculum recommends a range of 40–50 units per semester. The total units actually taken may exceed the 360 unit minimum, but students are strongly encouraged to take the extra elective courses in whatever subjects they wish in order to enrich their backgrounds and enhance their educational experience.

Some students may need to earn more than 360 units to complete their degree. Usually this happens when students earn AP Credit for a course (for example 09-105) and then take a class with the same or similar content (take 09-105 at CMU or 09-107). You cannot count 20 units towards a 10-unit requirement so this student would need to earn 370 total units.

Notes on Electives

Chemistry Electives

A minimum of 18 units of chemical electives is required.

Chemical electives can be satisfied by 09-445 Undergraduate Research, or by most other chemistry courses 09-3xx or higher, undergraduate or graduate, for which the student has the necessary prerequisites, or by 03-231/03-232 Biochemistry I. Biochemistry also fulfills the Life Sciences requirement for the MCS technical breadth requirement. 09-435 Independent Study Chemistry, may only be used to fulfill this requirement with permission of the Director of Undergraduate Studies. Certain interdisciplinary courses (e.g. 39-xxx) relating to chemistry can also be used with permission by the Director of Undergraduate Studies. Chemistry electives are intended to enhance a student's technical knowledge in chemistry. Some chemistry courses are more interdisciplinary in nature and/or less technical in content. This applies to 09-510 Chemistry and Sustainability and 09-291 Environmental Systems on a Changing Planet plus 09-381 Environmental Systems on a Changing Planet: Science & Engineering Addendum. (Note: 09-291 without the addendum cannot count as a chemistry elective.) Only one of these two courses may be counted towards fulfillment of 18 units of chemistry electives.

The scheduling of these electives can vary and students should check with the department offering the course to see which courses are offered in any given year or semester and with the Director of Undergraduate Studies in the Department of Chemistry to ascertain whether the course is an acceptable chemistry elective.

Free Electives

Free electives are defined as including any course offered by Carnegie Mellon except those in science or engineering fields that are primarily intended for non-majors. A maximum of 9 units total of Physical Education and/or ROTC courses combined can be counted as free elective units. The Chemistry Department does not require technical electives.

B.S. in Chemistry/Biological Chemistry Track

This degree is ideal for students who wish to better prepare themselves for advanced studies in biological chemistry or biomedical fields and a job market that values knowledge and skills from both disciplines. A combination of advanced research-focused lecture course offerings and a novel laboratory course modeling the drug discovery process will allow students to build the strong foundation typical of a successful chemistry major, while expanding out into applications of chemistry in the biological sciences.

The suggested curriculum recommends that the required technical courses be completed at the earliest opportunity, however students have considerable flexibility to postpone these courses in favor of electives, allowing compatibility with the programs of other departments. In designing such programs for a minor or additional major with chemistry, students should note that certain required chemistry courses only are offered in specific semesters, not both. These include the Fall-only courses , 09-219 Modern Organic Chemistry, 09-321 Laboratory III: Molecular Design and Synthesis and 09-323 Bioorganic Chemistry Laboratory and 09-344 Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry as well as the Spring-only courses 09-331 Modern Analytical Instrumentation, 09-220 Modern Organic Chemistry II, 09-345 Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry and 09-348 Inorganic Chemistry. Also, in some cases, a course that is normally scheduled for the fall may be changed to a spring course (or the inverse) due to a departmental curriculum change or faculty availability.

Curriculum

This catalog and the sample schedules presented are intended to be used by students in the first year class entering in the fall of 2023. Upperclass students should refer to the appropriate previous version of the catalog published during their first year for the requirements that are specific to them.

The technical breadth requirement of the MCS core curriculum requires a minimum of four technical courses outside of the student's primary major. Chemistry majors in the Biological Chemistry Track must at minimum take the following non-chemistry technical courses: Physics I for Science Students (33-121, 12 units), Physics II for Biological Sciences & Chemistry Students (33-122, 9 units), Modern Biology (03-121, 9 units), Principles of Computing (15-110, 10 units) (or other approved programming course), 21-120 Differential and Integral Calculus (10 units) and Integration and Approximation (21-122, 10 units) **or** Calculus II for Biologists and Chemists (21-124, 10 units). Students should complete this technical core as early as possible and preferably by the end of their fifth semester. AP credit cannot be used to fulfill the technical breadth requirements for the core though AP classes can be used to fulfill prerequisites for chemistry classes.

The non-technical breadth requirements for MCS students includes Interpretation and Argument (76-101, 9 units), four courses with a minimum of 36 units from the arts, humanities or social sciences and a course of at least 9 units from an approved list in the category of Cultural/Global understanding, a course in the Science and Society category, a total of five ENGAGE courses including three ENGAGE in Wellness courses, ENGAGE in Wellness: Looking Inward (38-230, 1 units), ENGAGE in Wellness: Looking Outward (38-330, 1 units) and ENGAGE in Wellness: Looking Forward (38-430, 1 units), as well as ENGAGE in Service (38-110, 1 units) and ENGAGE in the Arts (38-220, 2 units) plus EUREKA!: Discovery and Its Impact (38-101, 6 units) the MCS first-year seminar for a minimum of 72 units.

The Science and Society requirement as well as the ENGAGE courses must be finished **prior** to your final semester at CMU (no later than your penultimate semester). The Science and Society requirement can be fulfilled in numerous ways via MCS classes and other disciplinary courses that can also fulfill other requirements for your degree (but can NOT double count within the general education categories i.e. a course used to fulfill Science and Society cannot also fulfill your Cultural Analysis requirement or count towards your 36 units of non-technical electives). In the chemistry department courses currently approved to fulfill the Science and Society requirement that can also count as a chemistry elective are 09-510 Chemistry and Sustainability , 09-291 Environmental Systems on a Changing Planet with 09-381 Environmental Systems on a Changing Planet: Science & Engineering Addendumand 09-403 Hooked: The Chemical Basis of Drug Addiction. A more expanded listing will be maintained by the MCS Dean's Office (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/index.html (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/)).

For more information on allowed courses in the arts, humanities and social sciences and electives in the Cultural/Global Understanding category refer to the MCS section of this catalog.

The following are only meant to represent sample schedules. Students should always consult with their academic advisor to discuss an individualized plan to meet their academic goals.

Freshman Year

Fall		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
21-120	Differential and Integral Calculus	10
33-121	Physics I for Science Students	12
76-101	Interpretation and Argument	9
38-101	EUREKA!: Discovery and Its Impact	6
99-101	Computing @ Carnegie Mellon	3
		50

Students interested in majoring in chemistry who have a strong chemistry background, should enroll in 09-107 rather than 09-105. Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

There are some elective laboratory courses offered for MCS students in the first year. These include 03-117 Frontiers, Analysis, and Discovery in Biological Sciences or 09-115 Introduction to Undergraduate Research in Chemistry. The maximum units allowed during the first semester is 54; therefore, students wishing to take a lab should take an alternate technical course to Physics I such as 15-110 or 03-121 so that their unit total is lower.

Spring		Units
09-106	Modern Chemistry II *	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	
03-121	Modern Biology	9
or 33-121	Physics I for Science Students	
or 15-110	Principles of Computing	
xx-xxx	Arts, Humanities and Social Sciences Course 1	9
xx-xxx	Free Elective	5
		43

* Chemistry majors who place out of 09-106 can take 09-348 Inorganic Chemistry, 09-510 Chemistry and Sustainability as a chemistry elective, or other courses yet to be announced. Chemistry majors who feel they are ready for an undergraduate research experience should meet with the Director of Undergraduate Studies. These opportunities are more prevalent in the summer after your first year or sophomore year.

Sophomore Year

Fall		Units
09-201	Undergraduate Seminar I	1
09-219	Modern Organic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
33-122	Physics II for Biological Sciences & Chemistry Students Course is a prerequisite for 09-331, normally taken in the spring of the junior year	9
03-220	Genetics or other biological chemistry elective.	9
xx-xxx	Arts, Humanities and Social Sciences Course 2	9
		50

Spring		Units
09-202	Undergraduate Seminar II: Safety and Environmental Issues for Chemists	1
09-220	Modern Organic Chemistry II	10
09-222	Laboratory II: Organic Synthesis and Analysis	12
03-232	Biochemistry I	9
38-230	ENGAGE in Wellness: Looking Inward	1
xx-xxx	Arts, Humanities and Social Sciences Course 3	9
		42

Reminder about Flexible Scheduling: Student feedback indicates that the junior year BS schedule can feel quite intense as you move into the more mathematical and physical chemistry oriented curriculum, especially if you are also engaged in undergraduate research. Remember that the senior year in chemistry is essentially open for free electives. You may use this flexibility to spread out your junior year requirements over four semesters rather than two. You should consult with your academic advisor to explore alternative schedules if you are interested.

Junior Year

Fall		Units
09-301	Undergraduate Seminar III	1
09-231	Mathematical Methods for Chemists Math methods is a co-requisite for 09-344 and a prerequisite for 09-345 (spring). If you move math methods to the fall of your senior year, you must also move 09-344, 09-345 and 09-322 to the senior year.	9
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry Quantum is a prerequisite for Lab IV. If you move Quantum to the fall of the senior year, you must move Lab IV to the spring of the senior year. 09-344 is not a prerequisite for 09-345 (spring).	9
09-323	Bioorganic Chemistry Laboratory This lab class is not a prerequisite for 09-322; it can be moved to the fall of your senior year without impacting the spring junior year courses.	12
38-330	ENGAGE in Wellness: Looking Outward	1
xx-xxx	Arts, Humanities and Social Sciences Course 4	9
		41

Spring		Units
09-302	Undergraduate Seminar IV	1
09-322	Laboratory IV: Molecular Spectroscopy and Dynamics	12
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry This course is a co-requisite of Lab IV. If you move it to the senior year, you must also move Lab IV.	9
09-331	Modern Analytical Instrumentation This course is a co-requisite of Lab IV. If you move it to the senior year, you must also move Lab IV.	9
xx-xxx	Cultural/Global Understanding Requirement	9
xx-xxx	Approved Science and Society elective. This course can be scheduled at any point during your studies but prior to your final semester.	6-9
		46-49

Senior Year

Fall		Units
09-401	Undergraduate Seminar V	1
09-xxx	Biological Chemistry Elective 1 (see notes on electives)	9
09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates 09-718::or 09-719 will also fulfill this requirement.	9
or 09-519	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	
38-110	ENGAGE in Service	1
38-430	ENGAGE in Wellness: Looking Forward	1
38-220	ENGAGE in the Arts	2
xx-xxx	Free Electives	21
		44

Spring		Units
09-402	Undergraduate Seminar VI	3
09-348	Inorganic Chemistry	10
xx-xxx	Biological Chemistry Elective 2	9
xx-xxx	Biological Chemistry Elective 3	9
xx-xxx	Free Electives	18
		49

Distribution of Units

Minimum Total Chemistry Units 187; See distribution below.

Required Chemistry Courses*		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
09-106	Modern Chemistry II	10
09-219	Modern Organic Chemistry	10
09-220	Modern Organic Chemistry II	10
03-231	Honors Biochemistry	9
or 03-232	Biochemistry I	
09-231	Mathematical Methods for Chemists	9
09-331	Modern Analytical Instrumentation	9
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	9
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	9
09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates	9
or 09-519	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	
09-348	Inorganic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
09-222	Laboratory II: Organic Synthesis and Analysis	12
09-323	Bioorganic Chemistry Laboratory	12
09-322	Laboratory IV: Molecular Spectroscopy and Dynamics	12
09-xxx	Chemistry Seminars	8
09-xxx	Biological Chemistry Electives	27

Students who transfer into the department and have taken 09-217 Organic Chemistry I and/or 09-218 Organic Chemistry II, will be required to complete units of 09-435 Independent Study Chemistry, 1 unit per course, under the supervision of the instructor(s) for 09-219 and/or 09-220 in order to master the course content missed in this course sequence.

Students who transfer into the department and have taken 09-207 Techniques in Quantitative Analysis and/or 09-208 Techniques for Organic Synthesis and Analysis will be required to take a 3 unit transition course (09-215 Chemistry Tech I to Lab I Transition for 09-207 and/or 09-216 Chemistry Tech II to Lab II Transition for 09-208) to fulfill the major requirements for 09-221 and/or 09-222.

Chemistry courses required for the BS degrees that are numbered 09-2xx or higher must be taken at Carnegie Mellon University. Exceptions must be requested of and approved by the Director of Undergraduate Studies. In general such requests will be approved only under unusual or extenuating circumstances.

Other Requirements	**Units**
Modern Biology	**9**
Computer Science	**10**
Mathematics	**20**
Physics	**21**
Interpretation and Argument	**9**
Arts, Humanities and Social Sciences courses	**36**
Cultural/Global Understandling	**9**
EUREKA! (First Year Seminar)	**6**
Science and Society Elective	**6**
ENGAGE in Wellness (3 courses)	**3**
ENGAGE in Service	**1**
ENGAGE in the Arts	**2**
Computing @ Carnegie Mellon	**3**
Free Electives	**38**
Minimum number of units required for the degree:	**360**

The above B.S. curriculum recommends a range of 41–50 units/semester to meet the minimum degree requirement. Students are strongly encouraged to take extra elective courses (except in the first year) in whatever subjects they wish in order to enrich their backgrounds and enhance their educational experience.

Some students may need to earn more than 360 units to complete their degree. Usually this happens when students earn AP Credit for a course (for

example 09-105) and then take a class with the same or similar content (take 09-105 at CMU or 09-107). You cannot count 20 units towards a 10-unit requirement so this student would need to earn 370 total units.

NOTES ON ELECTIVES

Biological Chemistry Electives

A minimum of three biological chemistry electives for a total of 27 units or more is required.

A list of currently approved electives is provided below. Of the three elective courses at least two should be chemistry courses and a maximum of one can be taken in biology or physics. Exceptions can be granted by the Director of Undergraduate Studies. One semester of 09-445 for 9 units may be used for one biological chemistry elective with the approval of the Director of Undergraduate Studies. It must be part of a longer term experience ensuring depth of knowledge in the area.

09-403	Hooked: The Chemical Basis of Drug Addiction	9
09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates (One of these two courses is required for the degree. The other can be used as a Biological Chemistry elective.)	9
or 09-519	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	
09-521	Metals in Biology: Function and Reactivity	6
09-522	Kinetics and Mechanisms of Chemical and Enzymatic Reactions	9
09-538	Exposure and Risk Assessment for Environmental Pollutants	9
09-621	Welcome to the Future Lab - Science in the Cloud Must be taken with 09-623	6
09-623	Future Lab- DNA Science in the Cloud	6
09-737	Medicinal Chemistry and Drug Development	12
09-803	Chemistry of Gene Expression	12
03-220	Genetics	9
03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	9
03-320	Cell Biology	9
03-327	Evolutionary Bioinformatics: Trees, Sequences and the Comparative Method	9
03-344	Experimental Biochemistry	12
03-362	Cellular Neuroscience	9
03-366	Neuropharmacology: Drugs, Brain and Behavior	9
03-390	Molecular and Cellular Immunology	9
03-391	Microbiology	9
03-435	Cancer Biology	9
03-439	Introduction to Biophysics	10
03-442	Molecular Biology	9
03-729	Entrepreneurship and protein-based drug development	6
03-871	Structural Biophysics	12
33-441	Introduction to Biophysics	10

Free Electives

Free electives are defined as including any course offered by Carnegie Mellon except those in science or engineering fields that are primarily intended for non-majors. A maximum of 9 units total of Physical Education, StuCo and/or ROTC courses combined can be counted as free elective units. The Chemistry Department does not require technical electives.

Options for the Bachelor's Degrees in Chemistry

The curriculum for the degree Bachelor of Science in Chemistry permits students to take a number of elective courses in chemistry and other fields, particularly in the junior and senior years. Students may wish to complete a group of elective courses from several specialty areas, called “options,” to complement their technical education. Each option will complement the Bachelor's degree in Chemistry and will provide students with expertise in a specific area not covered by the normal undergraduate curriculum. Options are noted on the student's transcript but not on the diploma.

For each of the following options, the student should refer to the previous description of the curriculum for the B.S.or B.A. degrees in chemistry. Required courses are unchanged, and the courses that should be taken as electives for each option are listed below. Chemistry courses within an option also count towards fulfillment of the chemistry elective requirement for the B.S. degree. The courses can fulfill MCS technical core requirements (and in some cases non-technical core requirements i.e the management option) but there is very limited ability to count a course for an option and also for a minor or additional major/degree in a related area. You will need to consult with the appropriate advisors about double counting issues.

A student who completes the recommended courses for any of these options will receive a certificate from the Department of Chemistry at Commencement as formal evidence of the accomplishment and a notation of this will be made on the student's transcript.

BIOCHEMISTRY OPTION		Units
03-231/232	Honors Biochemistry (or Biochemistry)	9
09-518/718	Bioorganic Chemistry: Nucleic Acids and Carbohydrates	9
or 09-718	Bioorganic Chemistry: Nucleic Acids and Carbohydrates	
or 09-519	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	
or 09-719	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	
xx-xxx	2 Electives in Biochemistry	
Elective courses may be chosen from the following list. (Other courses listed as electives for the Biological Chemistry Track may be possible with permission.)		
03-344	Experimental Biochemistry	12
09-737	Medicinal Chemistry and Drug Development	12
09-803	Chemistry of Gene Expression	12
03-439	Introduction to Biophysics	10
09-519/719	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	9
or 09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates	
or 09-718	Bioorganic Chemistry: Nucleic Acids and Carbohydrates	

POLYMER SCIENCE OPTION		Units
09-502/741	Organic Chemistry of Polymers	9
09-760	The Molecular Basis of Polymer Mechanics	12
Two Electives in Polymer Science		9
Elective courses may be chosen from the following list		
09-445	Undergraduate Research (in a polymer area as approved by the Director of Undergraduate Studies and generally part of a longer term project)	9
09-509/715	Physical Chemistry of Macromolecules	9
09-736	Transition Metal Catalysis for Organic and Polymer Synthesis	12
27-477	Introduction to Polymer Science and Engineering	9
Other upper level courses in chemistry, biomedical engineering, materials science engineering or the colloids, polymers and surfaces program may be used with permission of the Director of Undergraduate Studies		

MATERIALS CHEMISTRY OPTION		Units
27-100	Engineering the Materials of the Future	12
27-201	Structure of Materials	9
Two Elective Courses of at least 9 units each from the list below		
27-202	Defects in Materials	9
09-445	Undergraduate Research (in a materials area as approved by the Director of Undergraduate Studies and generally part of a longer term project)	9
09-502/741	Organic Chemistry of Polymers	9
09-507/707	Nanoparticles	9
09-509/715	Physical Chemistry of Macromolecules	9
09-723	Proximal Probe Techniques: New Tools for Nanoscience & Nanotechnology	12
27-xxx	MSE course approved by Director of Undergraduate Studies	

ENVIRONMENTAL CHEMISTRY OPTION		Units
09-510/710	Chemistry and Sustainability 09-291::must be taken with 09-381 in order to count towards this requirement.	9
or 09-291	Environmental Systems on a Changing Planet	
09-524	Environmental Chemistry	9
Two elective courses of at least 9 units each from the list below		
09-445	Undergraduate Research 9 units of 09-445 can count towards this option if part of a longer term immersion and approved by the Director of Undergraduate Studies	Var.
09-225	Climate Change: Chemistry, Physics and Planetary Science	9
09-529/729	Introduction to Sustainable Energy Science	9
09-538	Exposure and Risk Assessment for Environmental Pollutants	9
or 09-738	Exposure and Risk Assessment for Environmental Pollutants	
19-440	Combustion and Air Pollution Control	9
12-651	Air Quality Engineering	9
12-657	Water Resource Systems Engineering	9
12-702	Fundamentals of Water Quality Engineering	12

MANAGEMENT OPTION		Units
70-100	Global Business Global Business is intended for first-year and sophomore students only. Juniors and seniors interested in pursuing the management option must replace the course with a constrained elective as defined for the Minor in Business Administration.	9
73-102	Principles of Microeconomics	9
70-122	Introduction to Accounting	9
Tepper Constrained Elective: As defined in the 2022-23 Undergraduate Catalog these must be one of the following courses: 70-311, 70-371, 70-381, or 70-391		9

COMPUTATIONAL CHEMISTRY OPTION		Units
15-112	Fundamentals of Programming and Computer Science	12
15-122	Principles of Imperative Computation	12
or 15-150	Principles of Functional Programming	
21-127	Concepts of Mathematics	12
09-563/763	Molecular Modeling and Computational Chemistry	9
xx-xxx	One Upper Level Computational Elective Course of at least 9 units from the list below	
09-621	Welcome to the Future Lab - Science in the Cloud Must be taken with 09-623	6
15-210	Parallel and Sequential Data Structures and Algorithms	12
15-213	Introduction to Computer Systems	12
15-214	Principles of Software Construction: Objects, Design, and Concurrency	12
33-241	Introduction to Computational Physics	9

B.S. in Chemistry with Departmental Honors

Outstanding students with an interest in research are encouraged to consider the Honors program by the beginning of the junior year. The program combines a slightly modified B.S. curriculum with close faculty-student contact in an individual research project, concluding with the student's presentation and defense of a Bachelor's degree honors thesis to a Thesis Committee.

The B.S. in Chemistry with Departmental Honors curriculum follows the general sequence of courses that is listed for the B.S. degree. The honors program specifies that one of the two **chemistry** electives be a 12-unit graduate course, numbered 09-7xx or higher, and that of the remaining free electives required to reach the minimum 360 units for the degree, at least two be undergraduate research (totaling at least 18 units) and one be 09-455 Honors Thesis (taken for 6 units). Students will be encouraged to do more than the minimum amount of research, so stipends from the research advisor or other sources such as a Summer Undergraduate Research Fellowship are sometimes available for summer B.S. honors research.

By the end of the penultimate semester, candidates for the B.S. in chemistry may apply to be admitted for candidacy to the Honors B.S. program. Applications are available on the department Canvas site for chemistry majors. To be accepted, students will be expected to have shown excellent performance in class work – normally at least a 3.2 average QPA- and outstanding progress in undergraduate research. A statement of support from their research advisor is also required. Upon acceptance into the program, a Thesis Committee must be identified, which will monitor the progress of the student. The committee shall consist of at least one member of the Undergraduate Program Committee to be appointed by the Director of Undergraduate Studies, the student's research advisor and a third faculty member agreed upon by the student and advisor. This third member can be from another department or institution and can be tenure track, teaching track or research track faculty. It is the student's responsibility to contact the proposed third member of their committee and confirm their participation.

A Box folder will be created for each degree candidate. Information relevant to their candidacy that includes for example the completed application and written work products including documents and slides should be uploaded to this folder. The folder will be accessible to the student, members of the Undergraduate Program Committee and the student's thesis committee.

A written thesis suitable for an Honors B.S. degree is required and should be a clear exposition in proper scientific format of a research project done for at least 18 units of credit in 09-445 Undergraduate Research. The thesis should describe a substantive new contribution to a particular field of research. This could include, but is not limited to, the discovery of a new phenomenon, studies that enhance our understanding of a previously reported phenomenon, or the development of a new method or technique. The student's Thesis Committee will evaluate the thesis via a public oral presentation followed by a private defense of the thesis before it approves the Honors degree. The written thesis must be supplied to the members of the student's Thesis Committee no later than 1 week prior to the scheduled public defense. The defense is usually scheduled to take place during April or early May of the senior year (for a May graduation date but will change accordingly fo an August or December graduation) and the Director of Undergraduate Studies will coordinate the selection of a suitable date. Students completing the B.S. with Departmental Honors in Chemistry will receive MCS College Honors as well.

The designations of MCS College Honors and Departmental Honors are noted on the transcript but not on the diploma. Only University Honors are noted on the diploma.

Honors B.S. - M.S. Program in Chemistry

Overview

Outstanding students seeking an advanced degree are encouraged to apply for admission to the B.S./M.S. Honors program as early as they can but only after having made some progress on a research project that could eventually be suitable for production of a Master's level thesis. Please note that this degree is available only with the B.S. in chemistry or the B.S. in Chemistry/Biological Chemistry Track and cannot be obtained by students pursuing a B.A. degree in chemistry. Typically, applications are submitted during the second half of the sophomore year but no later than the first semester of the junior year. (Later applications would only be considered in exceptional circumstances and would generally involve staying for a fifth year of study.) Participants will have the opportunity to earn in four years not only the degree B.S. in Chemistry with Departmental Honors, but also the degree Master of Science in Chemistry. This program is highly research intensive and is not appropriate for all students. Requirements include completing five graduate level courses as electives. (See notes on Honors B.S./M.S. electives.)

The schedule of courses for the B.S./M.S. program generally moves as many courses as possible forward in the curriculum, though this is not a requirement. This gives the student the following advantages: 1) greater perspective in selection of a research advisor, 2) greater maturity in performing independent research, and 3) the possibility of initiating the graduate course sequence in the junior year.

Application Process

A completed application, finished in collaboration with their thesis advisor, must be submitted to the Director of Undergraduate Studies who will then arrange for an application meeting with the student, research advisor and representatives of the department Undergraduate Program Committee. (The application is available on the Canvas site for undergraduate chemistry majors.) At this meeting the student is expected to give an oral presentation with visual aids that presents relevant background, a summary of work completed to date and a detailed plan for their thesis project including a projected timeline for completion of the thesis research and the thesis itself.

The presentation generally lasts around 15 minutes. The committee may have questions for the candidate and/or advisor .

Thesis Committee

Upon acceptance into the program, a Thesis Committee must be identified, which will monitor the progress of the student. The Director of Undergraduate Studies generally initiates this process. The committee shall consist of at least one member of the Undergraduate Program Committee appointed by the Director of Undergraduate Studies, the student's research advisor and a third faculty member agreed upon by the student and advisor. This third member can be from another department or institution and can be tenure track, teaching track or research track faculty. It is the student's responsibility to contact the third member of their committee, confirm their participation and notify the Director of Undergraduate Studies.

A Box folder will be created for each degree candidate. Information relevant to their candidacy that includes for example the completed application and written work products including documents and slides should be uploaded to this folder. The folder will be accessible to the student, members of the Undergraduate Program Committee and the student's thesis committee.

Research Engagement

The student is expected to keep the research advisor selected for the duration of the thesis project. Summer thesis research for 10 weeks in each summer following the sophomore and junior years is strongly suggested to assist the student in completing research of sufficient quantity and quality to complete their thesis. Students normally will be given stipends for their summer work either by their research advisor or by competing for a summer fellowship such as a Summer Undergraduate Research Fellowship available through the Undergraduate Research Office. A minimum of 30 units of 09-445 Undergraduate Research is required though this is rarely sufficient as the sole research experience. Participation in group seminars during the junior and senior years is expected. Students must present their research at least once at the Sigma Xi competition at Meeting of the Minds, the annual Carnegie Mellon undergraduate research symposium, typically at the end of the junior year. In addition, students must meet with their Thesis Committee at minimum each fall, though additional meetings may be required by the Thesis Committee, to update the committee on their progress and in the fall of the senior year must prepare a written summary of their research progress to date (5 pages) and their plans for the academic year (1 page). This report must state clearly what stage the work is in; it must be clear what work is complete and ready for publication.

Failure to maintain what the committee deems as suitable progress towards degree in either research or graduate coursework may result in release from the program. The final decision rests with the Director of Undergraduate Studies in consultation with the thesis committee.

A meeting with the thesis committee should occur during the first two weeks of the final semester. The purpose of this meeting is to determine whether the candidate has made sufficient progress in research to warrant the production of a suitably rigorous thesis towards an M.S. degree according to the planned upon schedule. If the student has not made appropriate progress, they may have the option of extending their time to degree or pursuing Departmental Honors through writing and defense of a senior honors thesis as described elsewhere in this catalog.

Preparation for Writing the Thesis and the Thesis Defense

By the end of the penultimate semester (normally fall of the senior year) the student should complete a thorough literature review to begin preparation for the introduction of their thesis.

At the start of the spring semester of the senior year (or their final semester if different), the student must submit a draft of the introduction for their thesis and a detailed outline of their methods, results and discussion sections to the Director of Undergraduate Studies who also chairs the Honors Committee. This will be distributed via Box and reviewed by the student's Thesis Committee.

Each student is required to submit a formal Masters Degree dissertation to the Chemistry Department in April of the senior year (for a May graduation date) or at least one week prior to the date set for the thesis defense. The thesis usually has an abstract, introduction, methods, results, discussion and conclusion sections with acknowledgements. It is common for a Masters dissertations to contain multiple chapters describing various aspects of the project. The student's Thesis Committee will evaluate the thesis via a public oral presentation followed by a private defense of the thesis before the Thesis Committee. The defense is usually scheduled to take place during April or early May of the senior year and the Director of Undergraduate Studies will coordinate the selection of a suitable date. The defense presentation generally lasts around 30-40 minutes.

The dissertation, written in proper scientific format, should describe the research project in considerable detail and must withstand the scrutiny of the Thesis Committee with respect to completeness. It need not be as extensive nor contain the element of student originality characteristic of a Ph.D. thesis; however it must contain results and conclusions that are of a high enough quality to be accepted as a publication in a respected research journal, though publication of the work is not a requirement of the degree program. The student should refer to the ACS Style Guide for recommendations on appropriate presentation and formatting of written text, tables, graphs, and figures. As for all M.S. degree candidates in the Department, the dissertation must be approved first by the research advisor before it can be distributed to the rest of the committee. Thus, it is essential to give the complete thesis or individual chapters to the advisor for feedback well before the one-week deadline for submission to the full committee.

Research productivity is the most important criterion for success at the evaluation points, but QPA is a strong secondary criterion. A minimum of 3.2 and strong progress in research are required to remain in the program. Candidates must also maintain a QPA of at least 3.0 in the five graduate level courses required for the degree.

Students who complete this program will receive the designations of Departmental Honors and MCS College Honors. These are designated on the transcript, not on the diploma. Only University Honors are denoted on the diploma.

Students completing the requirements for this degree receive two diplomas, one for the B.S. degree and another for the M.S. degree. Since this is a combined degree program both degrees are awarded at the same time; the awarding of the two degrees cannot be separated in time. It is not uncommon for students to extend their time to degree through the summer following their planned May graduation in order to finish writing and defense of their M.S. thesis. There students are able to walk with their graduating class in May, though they will not receive their diplomas until after their thesis defense and submission of their grade for 09-455.

Failure to make progress in research or coursework of sufficient quality and quantity in a timely fashion can result in a student being removed from this degree program (removal of the M.S. degree from their record). The decision will be made by the thesis committee and the Director of Undergraduate Studies. Violations of professional ethical standards can also result in a student's removal from the B.S.-M.S. program. This will not interfere with the student earning a B.S. degree, the BS with the Biological Chemistry Track or the B.S. degree with Departmental Honors, provided the appropriate requirements are met.

Notes on Honors B.S. - M.S. Graduate Level Electives

The B.S. - M.S. Honors degree requires the completion of five graduate level courses. Graduate courses in chemistry are typically those numbered 09-7xx or 09-8xx. Some courses numbered 09-6xx are remedial graduate level courses and not acceptable towards the degree requirements as the content overlaps extensively with required chemistry courses at the undergraduate level (an example is 09-611 Chemical Thermodynamics). Others are part of established M.S programs in the college and may be possible candidates for fulfillment of this requirement (examples being 09-615 Computational Modeling, Statistical Analysis and Machine Learning in Science and 09-621 Welcome to the Future Lab - Science in the Cloud that must be taken with 09-623 Future Lab- DNA Science in the Cloud). Graduate classes in chemistry are normally 12-unit courses (or two six unit minis numbered 09-7xx or 09-8xx counting as one graduate level course). However, in order not to penalize interdisciplinary studies which may be essential to a good thesis, up to three of the five required graduate chemistry courses may be at the advanced undergraduate level (the 9 unit 09-5xx versions), though the 09-7xx course is generally preferred as the additional 3-units of work often target work or skills important to graduate-level work. All advanced undergraduate level courses used to satisfy this requirement must be approved by the Director of Undergraduate Studies. Students must earn a grade of C or better in each of the five graduate or upper level undergraduate courses fulfilling the requirements for this degree and also in 09-455, Honors Thesis. In addition students must earn a minimum of a 3.0 average combined for the five graduate or upper level undergraduate courses, 09-445 Undergraduate Research and 09-455 Honors Thesis in order to fulfill their degree requirements.

Curriculum for Students Pursuing the Honors B.S. - M.S. in Chemistry

This catalog and the sample schedules presented are intended to be used by students in the first year class entering in the fall of 2023. Upperclass students should refer to the appropriate previous version of the catalog published during their first year for the requirements that are specific to them.

The technical breadth requirement of the MCS core curriculum requires a minimum of four technical courses outside of the student's primary major. Chemistry majors must at minimum take the following non-chemistry technical courses: 33-121 Physics I for Science Students, 33-122 Physics

II for Biological Sciences & Chemistry Students, either 03-121 Modern Biology **or** 03-231 Honors Biochemistry **or** 03-232 Biochemistry I, 15-110 Principles of Computing (or other approved programming course), 21-120 Differential and Integral Calculus and 21-122 Integration and Approximation **or** 21-124 Calculus II for Biologists and Chemists. Students should complete this technical core as early as possible and preferably by the end of their fifth semester. AP credit cannot be used to fulfill the technical breadth requirements for the core though AP classes can be used to fulfill prerequisites for chemistry classes.

The non-technical breadth requirements for MCS students includes Interpretation and Argument (76-101, 9 units), four courses with a minimum of 36 units from the arts, humanities or social sciences and a course of at least 9 units from an approved list in the category of Cultural/Global understanding, a course in the Science and Society category, a total of five ENGAGE courses including three ENGAGE in Wellness courses, ENGAGE in Wellness: Looking Inward (38-230, 1 units), ENGAGE in Wellness: Looking Outward (38-330, 1 units) and ENGAGE in Wellness: Looking Forward (38-430, 1 units), as well as ENGAGE in Service (38-110, 1 units) and ENGAGE in the Arts (38-220, 2 units) plus EUREKA!: Discovery and Its Impact (38-101, 6 units) the MCS first-year seminar for a minimum of 72 units.

The Science and Society requirement as well as the ENGAGE courses must be finished **prior** to your final semester at CMU (no later than your penultimate semester). The Science and Society requirement can be fulfilled in numerous ways via MCS classes and other disciplinary courses that can also fulfill other requirements for your degree (but can NOT double count within the general education categories i.e. a course used to fulfill Science and Society cannot also fulfill your Cultural Analysis requirement or count towards your 36 units of non-technical electives). In the chemistry department courses currently approved to fulfill the Science and Society requirement that can also count as a chemistry elective are 09-510 Chemistry and Sustainability , 09-291 Environmental Systems on a Changing Planet with 09-381 Environmental Systems on a Changing Planet: Science & Engineering Addendumand 09-403 Hooked: The Chemical Basis of Drug Addiction. A more expanded listing will be maintained by the MCS Dean's Office (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/index.html (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/)).

For more information on allowed courses in the arts, humanities and social sciences and electives in the Cultural/Global Understanding category refer to the MCS section of this catalog.

The suggested curriculum recommends that the required technical courses be completed at the earliest opportunity, however students have considerable flexibility to postpone these courses in favor of electives, allowing compatibility with the programs of other departments. In designing such programs for a minor or additional major with chemistry, students should note that certain required chemistry courses only are offered in specific semesters, not both. These include the Fall-only courses , 09-219 Modern Organic Chemistry, 09-321 Laboratory III: Molecular Design and Synthesis and 09-323 Bioorganic Chemistry Laboratory and 09-344 Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry as well as the Spring-only courses 09-331 Modern Analytical Instrumentation, 09-220 Modern Organic Chemistry II, 09-345 Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry and 09-348 Inorganic Chemistry. Also, in some cases, a course that is normally scheduled for the fall may be changed to a spring course (or the inverse) due to a departmental curriculum change or faculty availability.

The following are only meant to represent sample schedules. Students should always consult with their academic advisor to discuss an individualized plan to meet their academic goals.

Fall		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
21-120	Differential and Integral Calculus	10
33-121	Physics I for Science Students	12
38-101	EUREKA!: Discovery and Its Impact	6
76-101	Interpretation and Argument	9
99-101	Computing @ Carnegie Mellon	3
		50

Students interested in majoring in chemistry who have a strong chemistry background, should enroll in 09-107 rather than 09-105. Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

There are some elective laboratory courses offered for MCS students in the first year. These include03-117 Frontiers, Analysis, and Discovery in Biological Sciences and 09-115 Introduction to Undergraduate Research in Chemistry., which can serve as the prerequisite for the research shadowing course 09-116 Undergraduate Research Shadowing in Chemistry in the spring semester. The maximum units allowed during the first semester is 54; therefore, students wishing to take a lab should take an alternate technical course to Physics I such as 15-110 or 03-121 so that their unit total is lower.

Spring		Units
09-106	Modern Chemistry II Chemistry majors who place out of 09-106 can take 09-348 Inorganic Chemistry, 09-510 Chemistry and Sustainability as a chemistry elective or inquire with the Director of Undergraduate Studies about a suitable research placement.	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	
15-110	Principles of Computing	10
or 33-121	Physics I for Science Students	
or 03-121	Modern Biology	
xx-xxx	Arts, Humanities and Social Sciences Course 1	9
xx-xxx	Free Elective	9
		48

Sophomore Year

Fall		Units
09-219	Modern Organic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
09-201	Undergraduate Seminar I	1
33-122	Physics II for Biological Sciences & Chemistry Students This course is a prerequisite for 09-331, normally taken in the spring of the junior year.	9
09-445	Undergraduate Research	9
xx-xxx	Arts, Humanities and Social Sciences Course 2	9
		50

Spring		Units
09-202	Undergraduate Seminar II: Safety and Environmental Issues for Chemists	1
09-222	Laboratory II: Organic Synthesis and Analysis	12
09-220	Modern Organic Chemistry II	10
09-348	Inorganic Chemistry	10
38-230	ENGAGE in Wellness: Looking Inward	1
xx-xxx	Arts, Humanities and Social Sciences Course 3	9
		43

Summer

10 weeks Honors Research recommended

Reminder about Flexible Scheduling: Student feedback indicates that the junior year BS schedule can feel quite intense as you move into the more mathematical and physical chemistry oriented curriculum, especially if you are also engaged in undergraduate research. Remember that the senior year in chemistry is essentially open for free electives. You may use this flexibility to spread out your junior year requirements over four semesters rather than two. You should consult with your academic advisor to explore alternative schedules if you are interested.

Junior Year

Fall		Units
09-301	Undergraduate Seminar III	1
09-231	Mathematical Methods for Chemists	9
09-321	Laboratory III: Molecular Design and Synthesis	12
or 09-323	Bioorganic Chemistry Laboratory	
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	9
09-445	Undergraduate Research	9
38-330	ENGAGE in Wellness: Looking Outward	1
xx-xxx	Arts, Humanities and Social Sciences Course 4	9
		50

Spring		Units
09-302	Undergraduate Seminar IV	1

09-322	Laboratory IV: Molecular Spectroscopy and Dynamics	12
09-445	Undergraduate Research	6
09-xxx	Graduate Chemistry Course 1 of 5 (see notes on Honors B.S. - M.S. electives in the generalized program description)	9
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	9
09-331	Modern Analytical Instrumentation	9
xx-xxx	Approved Science and Society elective. This course can be scheduled at any point during your studies but prior to your final semester.	6-9
		52-55

Summer

10 weeks Honors Research recommended

Senior Year

Fall		Units
09-401	Undergraduate Seminar V	1
09-445	Undergraduate Research	9
09-xxx	Graduate Chemistry Course 2 of 5	12
09-xxx	Graduate Chemistry Course 3 of 5	12
xx-xxx	Cultural/Global Understanding	9
38-430	ENGAGE in Wellness: Looking Forward	1
38-110	ENGAGE in Service	1
		45

Spring		Units
09-402	Undergraduate Seminar VI	3
09-455	Honors Thesis	15
09-xxx	Graduate Chemistry Course 4 of 5	9
09-xxx	Graduate Chemistry Course 5 of 5	9
38-220	ENGAGE in the Arts	2
xx-xxx	Free Elective	9
		47

Distribution of Units

Minimum Total Chemistry Units (238, See distribution below)

Required Chemistry Courses		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
09-106	Modern Chemistry II	10
09-219	Modern Organic Chemistry	10
09-220	Modern Organic Chemistry II	10
09-231	Mathematical Methods for Chemists	9
09-331	Modern Analytical Instrumentation	9
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	9
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	9
09-348	Inorganic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
09-222	Laboratory II: Organic Synthesis and Analysis	12
09-321	Laboratory III: Molecular Design and Synthesis	12
09-322	Laboratory IV: Molecular Spectroscopy and Dynamics	12
09-xxx	Chemistry Seminars	8
09-445	Undergraduate Research (in addition 2 summers recommended)	30
09-xxx	Graduate chemistry courses (see Notes on B.S./ M.S. Electives)	51-60
09-455	Honors Thesis	15

Students who transfer into the department and have taken 09-217 Organic Chemistry I, and/or 09-218 Organic Chemistry II, will be required to complete units of 09-435 Independent Study Chemistry, 1 unit per course, under the supervision of the instructor(s) for 09-219 and/or 09-220 in order to master the course content missed in this course sequence.

Students who transfer into the department and have taken 09-207 Techniques in Quantitative Analysis and/or 09-208 Techniques for Organic Synthesis and Analysis will be required to take a 3 unit transition course (09-215 Chemistry Tech I to Lab I Transition for 09-207 and/or 09-216 Chemistry Tech II to Lab II Transition for 09-208) to fulfill the major requirements for 09-221 and/or 09-222.

Chemistry courses required for the B.S. - M.S. degree that are numbered 09-2xx or higher must be taken at Carnegie Mellon University. Exceptions must be requested of and approved by the Director of Undergraduate Studies. In general such requests will be approved only under unusual or extenuating circumstances.

Other Requirements	**Units**
Biology	**9**
Computer Science	**10**
Mathematics	**20**
Physics	**21**
Interpretation and Argument	**9**
Arts, Humanities and Social Sciences courses	**36**
Cultural/Global Understanding	**9**
EUREKA! (first year seminar)	**6**
Science and Society Elective	**6**
ENGAGE in Wellness (3 courses)	**3**
ENGAGE in Service	**1**
ENGAGE in the Arts	**2**
Computing @ Carnegie Mellon	**3**
Free Electives	**6-15**
Minimum number of units required for degrees:	**388**

The above B.S. curriculum recommends a range of 41–55 units per semester to meet the minimum degree requirement of 388 units. Students are strongly encouraged to take extra elective courses (except in the first year) in whatever subjects they wish in order to enrich their backgrounds and enhance their educational experience.

Some students may need to earn more than 388 units to complete their degree. Usually this happens when students earn AP Credit for a course (for example 09-105) and then take a class with the same or similar content (take 09-105 at CMU or 09-107). You cannot count 20 units towards a 10-unit requirement so this student would need to earn 398 total units.

Free Electives

Free electives are defined as including any course offered by Carnegie Mellon except those in science or engineering fields that are primarily intended for non-majors. A maximum of 9 units total of Physical Education, StuCo and/or ROTC courses combined can be counted as free elective units. The Chemistry Department does not require technical electives.

Curriculum for Students Pursuing the B.S. in Chemistry/ Biological Chemistry Track-M.S. Degree in Chemistry

This catalog and the sample schedules presented are intended to be used by students in the first year class entering in the fall of 2023. Upperclass students should refer to the appropriate previous version of the catalog published during their first year for the requirements that are specific to them.

The technical breadth requirement of the MCS core curriculum requires a minimum of four technical courses outside of the student's primary major. Chemistry majors must at minimum take the following non-chemistry technical courses: 33-121 Physics I for Science Students, 33-122 Physics II for Biological Sciences & Chemistry Students, either 03-121 Modern Biology **or** 03-231 Honors Biochemistry **or** 03-232 Biochemistry I, 15-110 Principles of Computing (or other approved programming course), 21-120 Differential and Integral Calculus and 21-122 Integration and Approximation **or** 21-124 Calculus II for Biologists and Chemists. Students should complete this technical core as early as possible and preferably by the end of their fifth semester.

The non-technical breadth requirements for MCS students includes Interpretation and Argument (76-101, 9 units), four courses with a minimum of 36 units from the arts, humanities or social sciences and a course of at least 9 units from an approved list in the category of Cultural/ Global understanding, a course in the Science and Society category,

a total of five ENGAGE courses including three ENGAGE in Wellness courses, ENGAGE in Wellness: Looking Inward (38-230, 1 units), ENGAGE in Wellness: Looking Outward (38-330, 1 units) and ENGAGE in Wellness: Looking Forward (38-430, 1 units), as well as ENGAGE in Service (38-110, 1 units) and ENGAGE in the Arts (38-220, 2 units) plus EUREKA!: Discovery and Its Impact (38-101, 6 units) the MCS first-year seminar for a minimum of 72 units.

The Science and Society requirement as well as the ENGAGE courses must be finished **prior** to your final semester at CMU (no later than your penultimate semester). The Science and Society requirement can be fulfilled in numerous ways via MCS classes and other disciplinary courses that can also fulfill other requirements for your degree (but can NOT double count within the general education categories i.e. a course used to fulfill Science and Society cannot also fulfill your Cultural Analysis requirement or count towards your 36 units of non-technical electives). In the chemistry department courses currently approved to fulfill the Science and Society requirement that can also count as a chemistry elective are 09-510 Chemistry and Sustainability , 09-291 Environmental Systems on a Changing Planet with 09-381 Environmental Systems on a Changing Planet: Science & Engineering Addendumand 09-403 Hooked: The Chemical Basis of Drug Addiction. A more expanded listing will be maintained by the MCS Dean's Office (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/index.html (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/)).

For more information on allowed courses in the arts, humanities and social sciences and electives in the Cultural/Global Understanding category refer to the MCS section of this catalog.

The suggested curriculum recommends that the required technical courses be completed at the earliest opportunity, however students have considerable flexibility to postpone these courses in favor of electives, allowing compatibility with the programs of other departments. In designing such programs for a minor or additional major with chemistry, students should note that certain required chemistry courses only are offered in specific semesters, not both. These include the Fall-only courses , 09-219 Modern Organic Chemistry, 09-321 Laboratory III: Molecular Design and Synthesis and 09-323 Bioorganic Chemistry Laboratory and 09-344 Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry as well as the Spring-only courses 09-331 Modern Analytical Instrumentation, 09-220 Modern Organic Chemistry II, 09-345 Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry and 09-348 Inorganic Chemistry. Also, in some cases, a course that is normally scheduled for the fall may be changed to a spring course (or the inverse) due to a departmental curriculum change or faculty availability.

The following are only meant to represent sample schedules. Students should always consult with their academic advisor to discuss an individualized plan to meet their academic goals.

Freshman Year

Fall		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
21-120	Differential and Integral Calculus	10
33-121	Physics I for Science Students	12
or 03-121	Modern Biology	
76-101	Interpretation and Argument	9
38-101	EUREKA!: Discovery and Its Impact	6
99-101	Computing @ Carnegie Mellon	3
		50

Students interested in majoring in chemistry who have a strong chemistry background, should enroll in 09-107 rather than 09-105. Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

There are some elective laboratory courses offered for MCS students in the first year. These include 03-117 Frontiers, Analysis, and Discovery in Biological Sciences or 09-115 Introduction to Undergraduate Research in Chemistry. The maximum units allowed during the first semester is 54; therefore, students wishing to take a lab should take an alternate technical course to Physics I such as 15-110 or 03-121 so that their unit total is lower.

Spring		Units
09-106	Modern Chemistry II *	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	
03-121	Modern Biology	9
or 33-121	Physics I for Science Students	
or 15-110	Principles of Computing	
xx-xxx	Arts, Humanities and Social Sciences Course 1	9
xx-xxx	Free Elective	5
		43

* Chemistry majors who place out of 09-106 can take 09-348 Inorganic Chemistry, 09-510 Chemistry and Sustainability as a chemistry elective, or other courses yet to be announced. Chemistry majors who feel they are ready for an undergraduate research experience should meet with the Director of Undergraduate Studies. These opportunities are more prevalent in the summer after your first year or sophomore year.

Sophomore Year

Fall		Units
09-201	Undergraduate Seminar I	1
09-219	Modern Organic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
33-122	Physics II for Biological Sciences & Chemistry Students Course is a prerequisite for 09-331, normally taken in the spring of the junior year. This ourse can be delayed until a subsequent semester in order to better manage workload.	9
03-220	Genetics or other biological chemistry elective.	9
xx-xxx	Arts, Humanities and Social Sciences Course 2	9
		50

Spring		Units
09-202	Undergraduate Seminar II: Safety and Environmental Issues for Chemists	1
09-220	Modern Organic Chemistry II	10
09-222	Laboratory II: Organic Synthesis and Analysis	12
03-232	Biochemistry I	9
38-230	ENGAGE in Wellness: Looking Inward	1
xx-xxx	Arts, Humanities and Social Sciences Course 3	9
		42

Summer Research: 10 weeks of summer research is recommended

Reminder about Flexible Scheduling: Student feedback indicates that the junior year BS schedule can feel quite intense as you move into the more mathematical and physical chemistry oriented curriculum, especially if you are also engaged in undergraduate research. Remember that the senior year in chemistry is essentially open for free electives. You may use this flexibility to spread out your junior year requirements over four semesters rather than two. You should consult with your academic advisor to explore alternative schedules if you are interested.

Junior Year

Fall		Units
09-301	Undergraduate Seminar III	1
09-231	Mathematical Methods for Chemists Math methods is a co-requisite for 09-344 and a prerequisite for 09-345 (spring). If you move math methods to the fall of your senior year, you must also move 09-344, 09-345 and 09-322 to the senior year.	9

09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry Quantum is a prerequisite for Lab IV. If you move Quantum to the fall of the senior year, you must move Lab IV to the spring of the senior year. 09-344 is not a prerequisite for 09-345 (spring).	9
09-323	Bioorganic Chemistry Laboratory This lab class is not a prerequisite for 09-322; it can be moved to the fall of your senior year without impacting the spring junior year courses.	12
09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates One course from the set 09-518, 718, 519, 719 is required for the track.	9
38-330	ENGAGE in Wellness: Looking Outward	1
xx-xxx	Arts, Humanities and Social Sciences Course 4	9
		50

Spring		Units
09-302	Undergraduate Seminar IV	1
09-322	Laboratory IV: Molecular Spectroscopy and Dynamics	12
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry This course is a co-requisite of Lab IV. If you move it to the senior year, you must also move Lab IV.	9
09-331	Modern Analytical Instrumentation This course is a co-requisite of Lab IV. If you move it to the senior year, you must also move Lab IV.	9
xx-xxx	Cultural/Global Understanding Requirement	9
xx-xxx	Track Elective #2 (if you choose a class at the 09-5xx, 7xx or 8xx level it can double count for the track and the graduate classes for the MS degree.**)	
xx-xxx	Approved Science and Society elective. This course can be scheduled at any point during your studies but prior to your final semester.	6-9
		46-49

** Double counting: One of the required bioorganic courses and an appropriate, upper level undergraduate or graduate level chemistry class can double count towards the three track electives and the five required graduate courses for the MS degree. This is reflected in the schedule below.

Summer Research:10 weeks of summer research is recommended

Senior Year

Fall		Units
09-401	Undergraduate Seminar V	1
09-xxx	Biological Chemistry Elective 3 (see notes on Biological Chemistry electives)	9
xx-xxx	Graduate Course 1 (see notes in general description of BS-MS degrees)	9-12
xx-xxx	Graduate Course 2	9-12
38-110	ENGAGE in Service	1
38-430	ENGAGE in Wellness: Looking Forward	1
38-220	ENGAGE in the Arts	2
xx-xxx	Free Electives	16-23
		48-61

Spring		Units
09-402	Undergraduate Seminar VI	3
09-348	Inorganic Chemistry	10
xx-xxx	Graduate Course 3	9-12
09-455	Honors Thesis	15
xx-xxx	Free Electives	9
		46-49

DISTRIBUTION OF UNITS

Minimum Total Chemistry Units 271; See distribution below

Required Chemistry Courses*		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
09-106	Modern Chemistry II	10
09-219	Modern Organic Chemistry	10
09-220	Modern Organic Chemistry II	10
03-231	Honors Biochemistry	9
or 03-232	Biochemistry I	
09-231	Mathematical Methods for Chemists	9
09-331	Modern Analytical Instrumentation	9
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	9
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	9
09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates either 09-718 or 09-719 can also fulfill this requirement	9
or 09-519	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	
09-348	Inorganic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
09-222	Laboratory II: Organic Synthesis and Analysis	12
09-323	Bioorganic Chemistry Laboratory	12
09-322	Laboratory IV: Molecular Spectroscopy and Dynamics	12
09-xxx	Chemistry Seminars	8
09-xxx	Biological Chemistry Electives	27
09-445	Undergraduate Research	30
09-455	Honors Thesis	15
09-5xx/7xx graduate classes for the MS (3-4 required depending upon double counting)		27-48

Students who transfer into the department and have taken 09-217 Organic Chemistry I and/or 09-218 Organic Chemistry II, will be required to complete units of 09-435 Independent Study Chemistry, 1 unit per course, under the supervision of the instructor(s) for 09-219 and/or 09-220 in order to master the course content missed in this course sequence.

Students who transfer into the department and have taken 09-207 Techniques in Quantitative Analysis and/or 09-208 Techniques for Organic Synthesis and Analysis will be required to take a 3 unit transition course (09-215 Chemistry Tech I to Lab I Transition for 09-207 and/or 09-216 Chemistry Tech II to Lab II Transition for 09-208) to fulfill the major requirements for 09-221 and/or 09-222.

Chemistry courses required for the B.S. degrees that are numbered 09-2xx or higher must be taken at Carnegie Mellon University. Exceptions must be requested of and approved by the Director of Undergraduate Studies. In general such requests will be approved only under unusual or extenuating circumstances.

** Double counting: A maximum of one of the required bioorganic courses and an appropriate, upper level undergraduate or graduate level chemistry class can double count towards the three track electives and the five required graduate courses for the MS degree.

Other Requirements	Units
Modern Biology	**9**
Computer Science	**10**
Mathematics	**20**
Physics	**21**
Interpretation and Argument	**9**

Arts, Humanities and Social Sciences courses	**36**
Cultural/Global Understandling	**9**
EUREKA! (First Year Seminar)	**6**
Science and Society Elective	**6**
ENGAGE in Wellness (3 courses)	**3**
ENGAGE in Service	**1**
ENGAGE in the Arts	**2**
Computing @ Carnegie Mellon	**3**
Free Electives	**15**
Minimum number of units required for the degree:	**388**

The above B.S. curriculum recommends a range of 41–50 units/semester to meet the minimum degree requirement. Students are strongly encouraged to take extra elective courses (except in the first year) in whatever subjects they wish in order to enrich their backgrounds and enhance their educational experience.

Some students may need to earn more than 388 units to complete their degree. Usually this happens when students earn AP Credit for a course (for example 09-105) and then take a class with the same or similar content (take 09-105 at CMU or 09-107). You cannot count 20 units towards a 10-unit requirement so this student would need to earn 398 total units.

NOTES ON ELECTIVES

Biological Chemistry Electives

A minimum of three biological chemistry electives for a total of 27 units or more is required.

A list of currently approved electives is provided below. Of the three elective courses at least two should be chemistry courses and a maximum of one can be taken in biology or physics. Exceptions can be granted by the Director of Undergraduate Studies. One semester of 09-445 for 9 units may be used for one biological chemistry elective with the approval of the Director of Undergraduate Studies. It must be part of a longer term experience ensuring depth of knowledge in the area.

09-403	Hooked: The Chemical Basis of Drug Addiction	9
09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates (One of these two courses is required for the degree. The other can be used as a Biological Chemistry elective.)	9
or 09-519	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	
09-538	Exposure and Risk Assessment for Environmental Pollutants	9
or 09-738	Exposure and Risk Assessment for Environmental Pollutants	
09-521	Metals in Biology: Function and Reactivity	6
09-737	Medicinal Chemistry and Drug Development	12
09-803	Chemistry of Gene Expression	12
03-220	Genetics	9
03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	9
03-320	Cell Biology	9
03-327	Evolutionary Bioinformatics: Trees, Sequences and the Comparative Method	9
03-344	Experimental Biochemistry	12
03-362	Cellular Neuroscience	9
03-366	Neuropharmacology: Drugs, Brain and Behavior	9
03-390	Molecular and Cellular Immunology	9
03-435	Cancer Biology	9
03-391	Microbiology	9
03-439	Introduction to Biophysics	10
03-442	Molecular Biology	9
03-729	Entrepreneurship and protein-based drug development	6
03-871	Structural Biophysics	12
33-441	Introduction to Biophysics	10

Free Electives

Free electives are defined as including any course offered by Carnegie Mellon except those in science or engineering fields that are primarily intended for non-majors. A maximum of 9 units total of Physical Education, StuCo and/or ROTC courses combined can be counted as free elective units. The Chemistry Department does not require technical electives.

Minor in Chemistry

In order for a student to receive a minor in Chemistry in conjunction with a B.S. or B.A. degree from another (primary) department, the successful completion of six courses as distributed below is required. Students pursuing the minor must inform the Chemistry Department of their intentions in writing using the MCS form for declaration of a minor so that the minor designation can be approved prior to graduation. The form may be obtained from the MCS undergraduate webpage at www.cmu.edu/mcs/undergrad/advising/forms (http://www.cmu.edu/mcs/undergrad/advising/forms/). **It should be completed and submitted to the department office, DH 1317 (or keishawd@andrew.cmu.edu), no later than the end of the course add period of the final semester prior to graduation.** If you decide at a later date not to complete the minor, it would be helpful to notify the Director of Undergraduate Studies, ks01@andrew.cmu.edu, so that it can be removed from your record. Minors are listed on the transcript but not on the diploma.

Note: An introductory chemistry class equivalent to either 09-105 Introduction to Modern Chemistry I or 09-107 Honors Chemistry: Fundamentals, Concepts and Applications is a **presumed prerequisite** to beginning the minor in chemistry.

Course Requirements

A. Four Required Core Courses

09-106	Modern Chemistry II	10
09-221	Laboratory I: Introduction to Chemical Analysis	9-12
or 09-207	Techniques in Quantitative Analysis	
09-217	Organic Chemistry I	9-10
or 09-219	Modern Organic Chemistry	
Choice of one of the following courses:		
09-331	Modern Analytical Instrumentation	9
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	9
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	9
09-348	Inorganic Chemistry	10
09-507	Nanoparticles	9
09-529	Introduction to Sustainable Energy Science	9

Courses in this group that are not used to satisfy Part A core courses may be used to satisfy elective course requirements in part B below, provided they are **not** required by the student's primary department. A single course cannot count as a requirement and one of two electives.

B. Two Elective Courses from the following list.

09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	9
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	9
09-348	Inorganic Chemistry	10
09-222	Laboratory II: Organic Synthesis and Analysis	9-12
or 09-208	Techniques for Organic Synthesis and Analysis	
09-218	Organic Chemistry II	9-10
or 09-220	Modern Organic Chemistry II	
03-231/232	Honors Biochemistry	9
09-403	Hooked: The Chemical Basis of Drug Addiction	9
09-502	Organic Chemistry of Polymers	9
09-507	Nanoparticles	9
09-510	Chemistry and Sustainability 09-291::must be taken with 09-381 in order to count as a chemistry elective. Chemistry electives are intended to enhance a student's technical knowledge in chemistry. Some chemistry courses are more interdisciplinary in nature and/or less technical in content. This applies to 09-510 Chemistry and Sustainability and 09-291 Environmental Systems on a Changing Planet plus 09-381 Environmental Systems on a Changing Planet: Science & Engineering Addendum. Only one of these two courses may be counted towards this requirement.	9

or 09-291	Environmental Systems on a Changing Planet	
09-524	Environmental Chemistry	9
09-525	Transition Metal Chemistry	9
09-538	Exposure and Risk Assessment for Environmental Pollutants	9
09-563	Molecular Modeling and Computational Chemistry	9
09-621	Welcome to the Future Lab - Science in the Cloud must be taken with 09-623	6
09-714	Advanced Organic Chemistry	12
09-737	Medicinal Chemistry and Drug Development	12
09-760	The Molecular Basis of Polymer Mechanics	12
09-xxx	Approved Upper Level Chemistry Course (must be 09-3xx or higher but see exclusions noted below)	

Courses in this section (part B above) can not be counted toward the minor if they are required **in any way** by the student's primary department or towards an additional major or minor other than as a free elective. For example, students majoring in Biological Sciences can not double count 03-231 (or 03-232), 09-208 (or 09-222), or 09-218 (or 09-220) toward the elective courses for the minor in chemistry. Chemical engineering majors can not count 03-231 (or 03-232) or a chemistry course that is used to satisfy that department's required chemistry or advanced chem/biochem elective.

09-231 Mathematical Methods for Chemists, does not count towards the minor in chemistry. The undergraduate research course 09-445 Undergraduate Research and 09-435 Independent Study Chemistry cannot be used for the minor.

Transfer credit will be accepted only for the prerequisite 09-105, or 09-106 and 09-217. All other classes towards the chemistry minor must be completed at Carnegie Mellon University.

Transfer Credit for Chemistry Courses

1. Requests for transfer credit for chemistry classes taken at other institutions should be made to Dr. Len Vuocolo, Associate Teaching Professor in the Department of Chemistry. Students making such requests should follow the policies and procedures in place within their home colleges in assembling materials for such requests. Consult with your advisor on the appropriate steps.
2. Requests should be placed **before** paying tuition for a class in case transfer credit is denied. Allow 1-2 weeks for approval.
3. At minimum requests must be accompanied by a complete syllabus including the textbook that will be used, a detailed list of topic areas and an indication of whether or not the course is part of the curriculum for science majors at the other institution. Check to ensure that the institution is on a semester system. Most schools on a quarter system (many in the UC system of schools) teach general chemistry and organic chemistry over three quarters each; therefore one of these classes would not be equivalent to one CMU class.
4. The department no longer accepts fully online courses.
5. No transfer credit will be awarded for the laboratory classes required for the chemistry or biology major at Carnegie Mellon University, 09-207, 09-221, 09-208, 09-222, 09-321, 09-323 and 09-322. Requests for transfer credit for 09-101, Introduction to Experimental Chemistry, will be accepted with the appropriate documentation.
6. In assessing the suitability of courses for transfer credit, the following factors are considered:
    - The rigor of the course must be comparable to that offered at Carnegie Mellon. This is usually assessed via the quality of the institution and its chemistry program, the textbook used and the amount of time spent on topic areas. In general, the rate of approval is significantly higher for four-year institutions with science majors as opposed to community colleges.
    - The topic areas should match to a degree of at least 80% those covered in the comparable course at Carnegie Mellon University.
7. 09-105 Introduction to Modern Chemistry I focuses primarily on structure, bonding, interactions (and their influence on properties), and reactions (including quantitative relationships among substances in them). Detailed topics include the following:

- Radiation and Its Interaction with Matter
- Quantum Mechanics (wave-particle duality of matter, Heisenberg Uncertainty Principle)
- Atomic Structure (Schrodinger Model, quantum numbers, interpretation of orbitals and their relative energies)
- Interpretation of Periodic Table, including the writing of electron configurations, Aufbau Principle, and Hund's Rule
- Periodic Table Trends in Elemental Properties
- Photoelectron Spectroscopy
- Bonding models and their explanation of properties (types of solids, bond polarity, bond energies, and bond lengths)
- Lewis Structures (octet rule and exceptions; formal charge)
- Resonance Structures
- Molecular shapes (including deviations from ideal bond angles)
- Molecular Polarity (greenhouse gases as application)
- Interparticle (intermolecular) forces and comparing or predicting relative physical properties from them (chromatography as application)
- Valence Bond (Localized Electron) and Molecular Orbital Theory
- Pi Molecular Orbitals (and energy diagrams) of Conjugated Organic Molecules
- Band Theory of Metals, Semiconductors, and Insulators
- Determining number of moles and chemical formulas
- Writing and balancing chemical equations (in particular completing combustion and double displacement reactions – including acid-base and precipitation reactions)
- Stoichiometry and thermochemical equations (heat evolved in combustion of fuels as application)
- Stoichiometry – limiting reactant and percentage yield
- Gases (mainly ideal) and stoichiometric applications involving them
- Phase transitions
- Solutions (determining concentrations, dilution problems, stoichiometric applications, application of solubility rules to determine if a precipitate forms)
- Acid-base reactions, titrations and other stoichiometric applications of acid-base reactions
- Oxidation Numbers, Redox Reactions/Titrations, and other stoichiometric applications of redox reactions

8. 09-106 Modern Chemistry II focuses primarily on thermodynamics, kinetics and equilibrium. Detailed topic areas include the following.

    - Thermochemistry and Thermodynamics (First, Second, and Third Laws, with gas expansion/compression applications, including reversible, adiabatic processes)
    - Internal energy, enthalpy, entropy, Gibbs Free energy, and determination of spontaneity
    - Kinetics : Determination of rate, order, rate laws (including application of pseudo-rate laws, application of integrated rate law to determine order, relationship between time and amount in a reaction, and half-life
    - Reaction mechanisms – applying fast equilibrium and steady-state approximations to determine rate law consistent with mechanism
    - Chemical Equilibrium : determination of Q and K expressions, determination of direction in which reaction proceeds to achieve equilibrium (using Q and Le Chatelier's principles, quantitative calculations to determine K or amounts at various stages, dependence of K on temperature, relationship between Gibbs Free energy, Q, and K)
    - Acid-Base Equilibria: writing dissociation equilibrium reactions and acid-base "neutralization" reactions, autoionization of water (determination of pH and pOH, use of K_w), writing K_a and K_b expressions from dissociation equilibria, quantitative equilibrium calculations for weak acids and bases, titrations between strong species, strong-weak species, and weak-weak species, buffers (calculations of pH and amounts, including how to make a buffer), polyprotic species (quantitative applications and titrations), solubility and precipitation equilibria, determination of K_{sp} expressions and quantitative applications of those expressions, complex ion formation equilibria, emphasis is placed on equilibrium problems that involve multiple types of simultaneous equilibria
    - Electrochemistry: Electrochemical cell notation and writing half-reactions from it, Faraday constant to connect number of moles of electrons / reaction amounts with current, connection of Gibbs Free Energy to cell voltage (potential) at equilibrium and non-equilibrium conditions, determination of *K*'s (acid-base, solubility constants) or amounts using Nernst equation in concentration cells (*K* for cell reaction)

9. 09-111 Nanolegos: Chemical Building Blocks takes an applications or systems approach to exploring current significant research and technology,

as well as to explaining phenomena and problems in the world around us. The major contexts and phenomena that it explore in applying and connecting chemical concepts are: (1) sustainable energy, (2) charge motion in materials, (3) natural versus engineered catalysts, (4) polymeric materials, and (5) reversible reactions in environmental and biological chemistry.

The chemical concepts used to promote an integrated understanding of the above applications and systems are:

- Radiation and Its Interaction with Matter
- Atomic Structure (Schrodinger Model, quantum numbers, interpretation of orbitals and their relative energies)
- Interpretation of Periodic Table, including the writing of electron configurations, Aufbau Principle, and Hund's Rule
- Periodic Table Trends in Elemental Properties
- Photoelectron Spectroscopy
- Bonding models and their explanation of properties (types of solids, bond polarity, bond energies, and bond lengths)
- molecular structures of organic and inorganic compounds
- Resonance Structures
- Molecular shapes
- Molecular Polarity
- Interparticle (intermolecular) forces and comparing or predicting relative physical properties from them
- Multiphase Reaction Stoichiometry (including limiting reactants and percent yield)
- Thermodynamics (First, Second, and Third Laws – applications more toward chemical reactions)
- Acid-Base Chemistry
- Kinetics (phenomenological and mechanistic)
- Electrochemistry (redox reactions; battery technology)
- o Equilibrium

10. 09-101 Introduction to Experimental Chemistry is a seven week (mini) laboratory course that is designed to introduce students to some basic laboratory skills, techniques, and equipment commonly used in experimental chemical investigations. The experiments will apply concepts in organic and inorganic synthesis, quantitative analysis using visible spectrophotometry, kinetics, acid-base chemistry, thermochemistry, and transition metal coordination chemistry.

The chemical concepts applied or discovered in the course are:

- molecular polarity and interparticle (intermolecular) forces
- synthesis of substances (empirical formulas, stoichiometry, and percent yield),
- spectrophotometric analysis (dilution and Beer-Lambert Law)
- kinetics (integrated rate laws and Arrhenius equation)
- equilibrium (Law of Mass Action, LeChâtelier's Principle)
- acid-base equilibria
- redox reactions
- thermochemistry (enthalpy, thermochemical equations)
- coordination chemistry
- The Laboratory Skills/Techniques involved are:
- safe lab practices, waste disposal, and chemical hygiene
- data/observation recording in lab notebook
- graphing, analyzing, and interpreting experimental data
- use of top-loading balance
- chromatography (paper or silica plate)
- filtration (gravity and vacuum)
- recrystallization of solids
- titrations (redox and acid-base; use of pH meter)
- making of and dilution of solutions (including quantitative transfer of solute)
- use of volumetric pipet
- use of spectrophotometer
- developing experimental procedures

Academic Advising

"*I really love how close-knit the Department becomes over the course of four years. We are a relatively small department, so we get to truly become a family by the end of our time here. I actually think that experiencing college during a pandemic has made us even closer. Everyone in the Department is so supportive of each other rather than being cutthroat, which I really loved. I also really loved getting to perform in Murder Mystery for three years, because it really connected me with the students from the other years within the Department.* " *~ 2022 Chemistry B.S.*

Building meaningful relationships related to your personal, academic and professional development should be a key component of your undergraduate experience. In the Department of Chemistry we believe that strong academic advising is key in facilitating this process. The Director of Undergraduate Studies is a Teaching Professor of Chemistry who acts as the academic advisor for all students with majors, additional majors and minors in chemistry. MCS students transition from their first year advisors in the Dean's Office to their department advisor once they declare their majors, generally in the spring of their first year.

In the Department of Chemistry we are committed to the MCS philosophy that holistic advising with attention to the development of the whole person in all dimensions is key to success at CMU. Your academic advisor is certainly available for the more transactional processes such as developing a course schedule that allows you to make appropriate progress towards your degree. However more importantly she is also available to both be a resource and to point you towards additional connections to enable success in all aspects of your experience. You are encouraged to connect with your advisor early and build this relationship through scheduled and impromptu visits and e-mail, social events throughout the year as well as in the classroom. You will engage with your advisor in classes and seminars throughout your time as a major, facilitating a strong working relationship that will promote discussions of your successes, challenges and areas related to your health and well-being.

"*It was such a welcoming place. I never felt competition or animosity among students. Since it was so small, it felt close-knit and like the professors really knew you.*" *~ 2022 Chemistry B.S.*

In the Department of Chemistry most students find additional faculty mentors in small, personalized classroom experiences but even more significantly through undergraduate research where participation generally exceeds 95% in any given graduating class.

Faculty

BRUCE A. ARMITAGE, Professor and Department Head of Chemistry, Co-Director Center for Nucleic Acids Science and Technology – Ph.D., University of Arizona; Carnegie Mellon, 1997–

STEFAN BERNHARD, Professor of Chemistry – Ph.D., University of Fribourg (Switzerland); Carnegie Mellon, 2009–

MARK E. BIER, Research Professor of Chemistry and Director of the Center for Molecular Analysis – Ph.D., Purdue University; Carnegie Mellon, 1996–

EMILE BOMINAAR, Associate Research Professor of Chemistry – Ph.D., University of Amsterdam (The Netherlands); Carnegie Mellon, 1994–

TERRENCE J. COLLINS, Teresa Heinz Professor in Green Chemistry and Director of the Institute for Green Science – Ph.D., University Auckland, (New Zealand); Carnegie Mellon, 1988–

SUBHA R. DAS, Associate Professor of Chemistry – Ph.D., Auburn University; Carnegie Mellon, 2006–

NEIL M. DONAHUE, Thomas Lord University Professor of Chemistry, Professor of Chemical Engineering and Engineering and Public Policy and Director of the Steinbrenner Institute for Environmental Education and Research – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2000–

SIMON FAULKNER, Assistant Teaching Professor of Chemistry at Carnegie Mellon University- Qatar – Ph.D., University College London (United Kingdom); Carnegie Mellon, 2019–

ISSAAC GARCIA-BOSCH, Associate Professor of Chemistry – Ph.D., University of Girona, Catalonia (Spain); Carnegie Mellon, 2021–

ROBERTO GIL, Research Professor of Chemistry and Director of the NMR Facility – Ph.D., Córdoba National University (Argentina); Carnegie Mellon, 2002–

GABRIEL DOS PASSOS GOMES, Assistant Professor of Chemistry and Chemical Engineering – Ph.D., Florida State University; Carnegie Mellon, 2022–

YISONG (ALEX) GUO, Associate Professor of Chemistry – Ph.D., University of California at Davis; Carnegie Mellon, 2014–

MICHAEL P. HENDRICH, Professor of Chemistry – Ph.D., University of Illinois; Carnegie Mellon, 1994–

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MARIA KURNIKOVA, Professor of Chemistry – Ph.D., University of Pittsburgh; Carnegie Mellon, 2003–

DANITH LY, Professor of Chemistry – Ph.D., Georgia Institute of Technology; Carnegie Mellon, 2001–

KRZYSZTOF MATYJASZEWSKI, J.C. Warner University Professor of Natural Sciences and Co-Director of the Center for Polymer-Based Protein Engineering and Director of the Center for Macromolecular Engineering – Ph.D., Polish Academy of Sciences (Poland); Carnegie Mellon, 1985–

CARRIE MCDONOUGH, Assistant Professor of Chemistry – Ph.D., University of Rhode Island; Carnegie Mellon, 2022–

NIMER MURSHID, Assistant Teaching Professor – Ph.D. , University of Waterloo; Carnegie Mellon, 2023-–

KEVIN NOONAN, Associate Professor of Chemistry – Ph.D., University of British Columbia (Canada); Carnegie Mellon, 2011–

LINDA A. PETEANU, Professor of Chemistry – Ph.D., University of Chicago; Carnegie Mellon, 1992–

GIZELLE SHERWOOD, Associate Teaching Professor – Ph.D. , Carnegie Mellon University; Carnegie Mellon, 2009–

GLORIA SILVA, Associate Teaching Professor of Chemistry – Ph.D., Universidad Nacional de Córdoba (Argentina); Carnegie Mellon, 2002–

KAREN H. STUMP, Teaching Professor of Chemistry and Director of Undergraduate Studies and Laboratories – M.S., Carnegie Mellon University; Carnegie Mellon, 1983–

RYAN SULLIVAN, Professor of Chemistry and Mechanical Engineering and Associate Director of the Institute for Green Science – Ph.D., University of California at San Diego; Carnegie Mellon, 2012–

STEFANIE SYDLIK, Associate Professor of Chemistry – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2015–

LEONARD VUOCOLO, Associate Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2005–

NEWELL WASHBURN, Associate Professor of Chemistry and Biomedical Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 2004–

DAVID YARON, Professor of Chemistry – Ph.D., Harvard University; Carnegie Mellon, 1992–

Emeriti

GUY C. BERRY, University Professor Emeritus of Chemistry and Polymer Science – Ph.D., University of Michigan; Carnegie Mellon, 1960–

JOSEF DADOK, Professor Emeritus of Chemical Instrumentation – Ph.D., Czechoslovak Academy of Sciences; Carnegie Mellon, 1967–

REA FREELAND – PhD, Carnegie Mellon University; Carnegie Mellon, 1993–

SUSAN T. GRAUL, Associate Teaching Professor Emerita of Chemistry – Ph.D., Purdue University; Carnegie Mellon, 1992–

PAUL J. KAROL, Professor Emeritus of Chemistry – Ph.D., Columbia University; Carnegie Mellon, 1969–

ECKARD MÜNCK, Professor Emeritus of Chemistry – Ph.D., Technical University of Darmstadt (Germany); Carnegie Mellon, 1990–

GARY D. PATTERSON, Professor Emeritus of Chemistry – Ph.D., Stanford University; Carnegie Mellon, 1984-.–

STUART W. STALEY, Professor Emeritus of Chemistry – Ph.D., Yale University; Carnegie Mellon, 1986–

Adjunct Faculty

BERNARD CRIMMINS, Adjunct Associate Professor of Chemistry and Associate Professor, Department of Civil Engineering, Clarkson University and President of Academic Environmental/Analytical Consulting Services (AEACS), LLC. – Ph.D., University of Maryland; Carnegie Mellon, 2018–

JOHN PETERSON MYERS, CEO and Chief Scientist of Environmental Health Sciences – Ph.D., University of California at Berkeley; Carnegie Mellon, 2010–

JAMES PETERSON, Adjunct Associate Professor of Chemistry and Associate Professor of Environmental and Occupational Health at the University of Pittsburgh – Ph.D., University of Essex, UK; Carnegie Mellon, 2004–

Courtesy

MICHAEL BOCKSTALLER, Professor of Materials Science Engineering and Faculty of Chemistry – Ph.D., Johannes Gutenberg University (Germany); Carnegie Mellon, 2005–

ANDREW GELLMAN, Lord Professor of Chemical Engineering and Co-Director W.E. Scott Institute for Energy Innovation – Ph.D., University of California, Berkeley; Carnegie Mellon, 1992–

NOA MAROM, Assistant Professor of Materials Science Engineering and Faculty of Chemistry – Ph.D., Weizmann Institute of Science (Israel); Carnegie Mellon, 2016–

GORDON RULE, Professor of Biological Sciences and Head of CMU Qatar Biological Sciences Program and Faculty of Chemistry – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1995–

ALAN J. RUSSELL, Highmark Distinguished Career Professor of Chemical Engineering and Director of Disruptive Health Technology Institute – Ph.D., Imperial College of London; Carnegie Mellon, 2012–

JAMES SCHNEIDER, Professor of Chemical Engineering and Faculty of Biomedical Engineering and Chemistry – Ph.D., University of Minnesota; Carnegie Mellon, 1999–

LYNN WALKER, Professor of Chemical Engineering and Faculty of Chemistry and Materials Science Engineering – Ph.D., University of Delaware; Carnegie Mellon, 1997–

JOHN L. WOOLFORD JR., Professor of Biological Sciences; Co-Director of Center for Nucleic Acids Science and Technology and Faculty of Chemistry – Ph.D., Duke University; Carnegie Mellon, 1979–