Chemistry

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The Department of Chemistry (www.holycross.edu/academics/chemistry/) is counted among the nation's top producers of chemistry graduates certified by the American Chemical Society. The Chemistry curriculum provides students with a solid background in fundamental principles and theories of chemistry with hands-on experience using state-of-the-art laboratory equipment. Students gain experience and knowledge in all the major areas of modern chemistry including organic, analytical, physical, inorganic, and biochemistry and have an opportunity to focus their program on a particular area of chemistry through research and elective courses. The overall curricular program is laboratory intensive, beginning with the Discovery Chemistry Core courses in general and organic chemistry. These courses use a guided inquiry approach, in which fundamental concepts are first encountered in the laboratory and subsequent lecture sessions are used to discuss and elaborate on the laboratory experience. Advanced courses build on this firm foundation, continuing to develop the skills and knowledge needed to become effective scientists and independent researchers. The program develops the verbal and written communication skills of students by emphasizing the importance of clarity in laboratory reports and oral presentations (required of all students who elect to do research).

A major strength of the Department is its undergraduate research program. Qualified students, working in association with faculty members, have an opportunity to conduct research in a wide range of chemistry fields during the academic year through one or more research courses (Chemistry 389, 390, 405/406, 407/408 and 410). Also, summer research positions with monetary stipends are usually available on a competitive basis. Involvement in a significant research project is strongly recommended for those majors interested in attending graduate school for an advanced degree in chemistry.

The Chemistry Major

Chemistry Majors are required to successfully complete at least 10 chemistry courses, with associated labs, as described below. Chemistry majors must also take two semesters of physics with lab (General Physics I & II or General Physics in Daily Life) and Calculus through Math 132, 134 or 136, normally by the end of the second year. Students who enjoy the quantitative and physical aspects of chemistry are also encouraged to take Methods of Physics (PHYS 221) or Multivariable Calculus (MATH 241) in preparation for physical chemistry and advanced study. Students wishing to receive an American Chemical Society certified degree in Chemistry must also successfully complete one course in biochemistry and be involved in a significant research project during the academic year (typically two research courses beyond CHEM 389 meet the requirement, e.g., CHEM 405 and 406).

All chemistry majors must begin with the Discovery Chemistry Core, which includes Atoms and Molecules (CHEM 181), Organic Chemistry 1 (CHEM 221), Organic Chemistry 2 (CHEM 222), and Equilibrium and Reactivity (CHEM 231). Each of these courses include lab and they are typically taken in the order listed above during the first and second year. Majors complete their chemistry curriculum with six advanced courses at the 300-level plus required labs (some formally associated with lecture courses, some taken as an overload along with the lecture course) which are typically taken in the third and fourth year. Any of our research courses can be taken more than once but students can not count more than three toward the 32 needed for graduation.

For the Class of 2010, the six advanced courses and four required labs, include Instrumental Chemistry and Analytical Methods 1 (CHEM 346), Classical Physical Chemistry (CHEM 336), Physical Chemistry Lab (CHEM 337), Modern Physical Chemistry (CHEM 335), Advanced Physical and Analytical Chemistry Lab (Fall course, new 2009), Inorganic Chemistry (CHEM 351), and two 300-level (non-research) elective courses. The combination of General Research 1 and 2 can count as an elective. We strongly recommend students begin the advanced sequence with CHEM 346.

For the Class of 2011, 2012, and 2013, the six advanced courses and four required labs include Instrumental Chemistry and Analytical Methods 1 (CHEM 346), Classical Physical Chemistry (CHEM 334), Physical Chemistry Lab, Modern Physical Chemistry (CHEM 335), Advanced Physical and Analytical Chemistry Lab (new, Fall 2009), Inorganic Chemistry and Biochemistry (CHEM301 or BIO301) and one 300-level (non-research) elective course. We strongly recommend students begin the advanced sequence with CHEM 346.

With the permission of the Chair of the Department, a student may substitute certain upper-division courses in physics, biology, or mathematics for one chemistry elective.

Departmental Honors Program

For the Class of 2010:

To be eligible to graduate with Department Honors, a student must maintain a minimum GPA of 3.0 within the major and overall, successfully complete two years of research (Chemistry 405/406 and Chemistry 407/408) and be nominated by his/her Research Advisor. Student proposals to substitute the second year of research with additional course work and/or a special project will also be considered.

For the Class of 2011, 2012 and 2013:

To graduate with Department Honors a student must have obtained a minimum GPA of 3.40 in all CHEM courses (as reported by the Registrar), taken two additional chemistry courses (which could include research courses) beyond the minimum 10 courses for the major, performed a sufficient quantity and quality of research as determined by the research advisor (or department chair for off-campus projects), and completed an acceptable honors-level capstone written project based on the research.

The Chemistry Minor

The chemistry minor is a seven-course program designed to allow students with an interest in chemistry an opportunity to participate in the exciting Discovery Chemistry core curriculum and to explore advanced work in one or more of the five foundation areas of chemistry: analytical, physical, inorganic, organic and biochemistry. All Chemistry Minors begin their curriculum with the Discovery Chemistry Core, which includes Atoms and Molecules (CHEM 181), Organic Chemistry 1 (CHEM 221), Organic Chemistry 2 (CHEM 222), and Equilibrium and Reactivity (CHEM 231). Chemistry Minors then choose and successfully complete three courses among the advanced 300-level (non-research) courses with one advanced lab. Biochemistry Lab (BIOL 303, 304 or equivalent), when taken in combination with an appropriate biochemistry course, (e.g., Biochemistry (new chemistry course, Fall 2008) or BIOL 301 or 302) can count as the advanced lab. Chemistry Minors are expected to complete prerequisites for advanced courses elected. Enrollment in the minor may be initiated as early as the second semester of the second year.

Biochemistry Concentration

The Departments of Biology and Chemistry jointly offer a concentration that focuses on the study of the chemistry underlying biological structure and function. Concentrators must be enrolled as either biology or chemistry majors. Participants take Biology 120 or 131, 301 and 302 with laboratories; Chemistry 181, 221, 222, 231 and 336 (or equivalent) and one additional biology course with an associated biochemistry-oriented laboratory, in addition to the usual courses required of their major. Chemistry majors will normally take Biology 301 and 302 with labs during their third year. Concentrators also complete a two-semester thesis project in their fourth year involving research on some aspect of biochemistry. Admission to the concentration is competitive and occurs in the second semester of the second year. Interested students should contact the chair of either department. Students enrolled in the Biochemistry Concentration are not eligible for the Chemistry Minor.

Other Programs Involving Chemistry

Environmental Studies Concentration: Students interested in concentrating in Environmental Studies are required to take a number of science courses. The Chemistry Department regularly offers environmentally related courses including Environmental Chemistry (CHEM 141), Equilibrium and Reactivity (CHEM 231), Instrumental Chemistry and Analytical Methods 1 (CHEM 346) and Environmental Forensics (CHEM 384). In addition, environmental capstone research projects are typically available in association with selected faculty members.

Premedical Program: Students in the premedical program must successfully complete the Discovery Chemistry Core (CHEM 181, 221, 222, 231), typically taken in the order listed and beginning in the first or second year.

Teacher Education Program: Students in the teacher education program will meet all chemistry requirements for certification as a secondary or middle school chemistry teacher in Massachusetts (MA Chemistry License), with successful completion of the Chemistry Major plus one course/project in the history and philosophy of science (e.g., PHIL 271). For the 2009-2010 classes, students should select one course in biochemistry as one of their electives. For the 2011 classes and beyond, this requirement is formally incorporated into the Chemistry Major. Formal application to the Teacher Education Program (TEP) and additional education courses are also required for licensure. Since Massachusetts teacher certification requirements continue to evolve, students should work closely with the Chemistry Department TEP Liaison to make sure all state requirements are met.

Advanced Placement Credit: Knowledge and experience gained in high school AP courses provide an excellent background for our Discovery Chemistry Core. While AP credit in Chemistry cannot be counted towards the minimum number of courses required in the major or advanced standing in the chemistry curriculum, this credit can count towards the 32-course graduation requirement.

Courses

Chemistry 110 — Methods of Chemistry *Alternate years*
Designed to reinforce problem-solving methods that are used in Atoms and Molecules, Organic 1, Organic 2, and Introduction to Equilibrium and Reactivity. The quantitative aspects of chemistry are emphasized. This course is not a prerequisite for any other chemistry course but will be helpful for those with a limited background in the sciences who plan to complete the four-semester introductory chemistry sequence (Chem 181, 221, 222, and 231). One unit.

Chemistry 141 — Environmental Chemistry *Alternate years*
Investigates the chemistry of the Earth's environment through systematic studies of our atmosphere, hydrosphere and lithosphere and the exchange and interplay between them. The primary focus of the course will be environmental change taking place today including those that threaten plant and animal habitats and pose hazards to human health. Understanding of our environment and current threats to it will be gained through a combination of readings, lectures, discussions, demonstrations, and problem sets. One unit.

Chemistry 144 — Chemistry and Society *Alternate years*
Acquaints non-science majors with chemistry as a human endeavor and helps them acquire some appreciation of the benefits and limitations of science. Readings from the current popular and scientific literature are examined to illustrate the relationships of science to society. Some of the basic concepts and principles of chemistry necessary for an understanding of environmental problems will be considered in detail. One unit.

Chemistry 181 — Atoms and Molecules *Fall*
This introductory general chemistry course leads students to explore in-depth the scientific method through the formulation and testing of hypotheses in the laboratory. Laboratory experiments lead students to discover basic principles, i.e., stoichiometric relationships, electronic configuration and molecular structure. Lectures will explain and expand upon laboratory results. This course is suitable for students seeking to satisfy the science distribution requirements. It is also the first course in the sequence for science majors and premedical students. One four-hour "discovery" laboratory session per week is included. One and one-half units.

Chemistry 221 — Organic Chemistry 1 *Spring*
A study of organic compounds from the points of view of the chemistry of the functional groups, modern structural theory and reaction mechanisms. The chemistry of aliphatic hydrocarbons, alkenes, alkynes, dienes, and alkyl halides is introduced in a discovery mode. Substitution, addition and elimination mechanisms are studied in detail. Emphasis is placed on stereochemistry. One four-hour "discovery" laboratory session per week is included. Students learn various techniques of separation, purification, and identification (chemical and spectroscopic) of organic compounds in the laboratory. There is an emphasis on one-step synthetic conversions which introduce the reactions to be studied in the lecture course. One four-hour "discovery" laboratory session per week is included. Prerequisite: Chemistry 181. (It is strongly recommended that students with a grade below C in Chemistry 181 do not continue with Chemistry 221 (see Chemistry 110)). One and one-half units.

Chemistry 222 — Organic Chemistry 2 *Fall*
A continuation of Chemistry 221. Aromatic compounds, alcohols, ethers, aldehydes, ketones, amines, carboxylic acids and their derivatives are studied. Aromatic substitution, acyl transfer and carbonyl condensation reactions are developed. The mechanistic implications and synthetic applications of these organic reactions are evaluated. One four-hour "discovery" laboratory session per week is included. Microscale synthetic techniques are included. Prerequisite: Chem 221. (A student should obtain a grade of C or better in Chemistry 221 to continue in Chemistry 222.) One and one-half units.

Chemistry 231 — Equilibrium & Reactivity *Spring*
Focuses on studying and understanding the role equilibrium, thermodynamics and kinetics play in chemical systems. Specific topics include phase and chemical equilibria, colligative properties of solutions, acid/base equilibria, chemical kinetics, electrochemistry, thermodynamics including enthalpy, entropy and free energy, and gas laws. Laboratory focused, this general chemistry course also introduces students to modern analytical instrumentation (such as UV-Vis spectrophotometer and GC-TCD) while developing critical wet chemical analytical techniques. Knowledge and skills gained in Chem 181, 221 and 222 will be built upon with an emphasis on obtaining quantitative understanding. One four-hour "discovery" laboratory session per week is included. Prerequisites: Chemistry 222 (or permission of Chair) and one semester of college calculus. One and one-half units.

Chemistry 299 — Special Topics *Annually*
Courses explore various topics in chemistry. The subject and format varies with each offering. One unit.

Chemistry 301 — Biochemistry *Annually*
A detailed study of the chemistry of biological molecules, with a focus on the structure of biological macromolecules and the chemical mechanism of biochemical transformations. Topics may include the structure and synthesis of proteins, nucleic acids, carbohydrates and lipids, enzymatic catalysis, biological thermodynamics, glycolysis and gluconeogenesis, the citric acid cycle, fatty acid oxidation, oxidative phosphorylation, and metabolic regulation. A strong background in thermodynamics and organic chemistry is highly recommended. This course may serve as a prerequisite for Biology 302. Students may not count both Biology 301 and Chemistry 301 for credit. Prerequisites: Chemistry 222 and 231. One unit.

Chemistry 304 — Synthetic Organic Chemistry *Every third year*
Covers a selection of modern synthetic methods and reagents used in organic chemistry. Topics to be presented include oxidation/reduction, organometallic reactions, functional group interconversions, protecting group strategies, enolate additions, and pericyclic reactions with a focus on asymmetric synthesis. The course

will build upon the individual methods discussed to ultimately demonstrate their combined use in the synthesis of complex organic molecules. Prerequisite: Chemistry 222. One unit.

Chemistry 309 — Spectroscopy *Every third year*
This course focuses on chemical structure identification through the interpretation of spectroscopic data. With a concentration on organic molecules, Mass, Vibrational (IR and Raman), and Magnetic Resonance (NMR and EPR) spectra are analyzed. There is an emphasis on NMR spectroscopy (including an introduction to modern multipulse techniques) to elucidate molecular structure. The course is conducted with a problem-solving approach and student participation is expected. Prerequisite: Chemistry 222. One unit.

Chemistry 310 — Bioorganic Chemistry *Every third year*
Focuses on chemistry of the major biochemical macromolecules: carbohydrates, proteins and nucleic acids. Topics discussed include structure determination and enzyme mechanisms relevant to chemical reactions involving these macromolecules. In addition, through the use of student presentations, the chemistry underlying the interaction of medicinal agents with these macromolecules is explored. Prerequisite: Chemistry 222. Prerequisite or Co-requisite: Chemistry 231. One unit.

Chemistry 317 — Nanotechnology *Every third year*
Introduces students to nanometer scale material and devices. Materials in this size regime often possess unusual properties that have application in molecular electronics, medical diagnostics and devices, molecular motors, and self-assembly and surface chemistry. Students will read a variety of books and scientific articles from peer reviewed journals. Nanotechnology is a multidisciplinary field of study where projects often require collaborations between chemists, physicists, biologists and engineers. Students other than chemistry majors who have completed the prerequisites are encouraged to enroll to broaden both their own perspective and that of the class. Prerequisites: Chemistry 222 and 231. One unit.

Chemistry 335 — Modern Physical Chemistry *Annually*
The course is a study of the basic concepts, principles and methods of modern physical chemistry. Physical chemistry asks "how?" and/or "why?" things happen as they do. Here, the emphasis will be on developing a deeper understanding of the microscopic properties that govern chemical phenomena. The topics covered may include quantum mechanics, statistical mechanics, spectroscopy, group theory, and computational chemistry. Prerequisites: Chemistry 336 and Mathematics 133, 134 or Mathematics 131, 132 or Mathematics 136 and Physics 111, 112 (with laboratory) or Physics 115, 116. One unit.

Chemistry 336 — Classical Physical Chemistry *Annually*
This course is a study of the basic concepts, principles and methods of classical physical chemistry. Physical chemistry asks "how?" and/or "why?" things happen as they do. Here, the emphasis will be on developing a deeper understanding of the macroscopic properties that govern chemical phenomena. The topics covered may include thermodynamics, chemical and phase equilibria, kinetics, reaction dynamics, statistical mechanics, and complex solution behavior. Prerequisites: Chemistry 231 and Mathematics 133, 134 or Mathematics 131, 132 or Mathematics 136 and Physics 111, 112 (with laboratory) or Physics 115, 116. One unit.

Chemistry 337 —Physical Chemistry Lab *Annually*
This advanced laboratory course is designed to teach students modern instrumental and computational methods used in physical chemistry and to develop student research skills. Students investigate classical and modern physical principles utilizing a variety of experimental and computation methods. The course introduces advanced data analysis techniques and develops student abilities to interpret data and communicate results in professional technical reports. The course fosters greater independence in the lab and advanced laboratory skills. Experiments complement Classical Physical Chemistry (Chemistry 336). One four-hour laboratory per week. Overload. Prerequisite or Co-requisite: Chemistry 336. One-half unit.

Chemistry 346 — Instrumental Chemistry and Analytical Methods 1 *Fall*
The application of instrumentation to chemical research and analysis has had a dramatic impact on the field of chemistry. As chemists, we must understand how instrumentation works in order to exploit its capabilities. This course focuses on spectroscopic, chromatographic and mass spectrometric methods of analysis. Specific analytical techniques included are molecular and atomic UV-Vis spectroscopy, infrared spectroscopy, TLC, GC, HPLC, and mass spectrometry (GC-MS). Laboratory and lecture work emphasize understanding instrumental design, major analytical methods of analysis and method development. When the student finishes this course he or she should be able to understand how and/or why instruments are designed to operate according to certain specific criteria and make intelligent choices among several possible ways of solving an analytical problem. Furthermore, the student should have confidence in his/her ability to work with modern

chemical instrumentation. One four-hour laboratory session per week is included. Prerequisite: Chemistry 231, prerequisite or corequisite: Physics 111 (with laboratory) or Physics 115. One and one-half units.

Chemistry 351 — Inorganic Chemistry *Spring*
Group theory and modern theories of bonding are used to discuss structural and dynamic features of inorganic compounds. The structure and bonding of transition metal coordination compounds are related to various reaction mechanisms. The principal structural and mechanistic features of transition metal organometallic chemistry are studied with emphasis on catalysis of organic reactions. The role of inorganic chemistry in biological systems is also explored. Prerequisite or Co-requisite: Chemistry 336. One unit.

Chemistry 389 — Introduction to Research *Fall, spring*
Involves a commitment to join a research group. Specific activities will be established with the individual Research Advisor but may include: attendance of group meetings, working on a lab or computer project with other group members, and/or reading/discussing literature related to group research. The course is by permission only. It is taken as an overload and receives no grade. It may be taken more than once. Interested students are invited to apply early in the fall or spring of the second, third or fourth year. The candidate's academic record will be reviewed to determine if the student could reasonably benefit from such a program. Prerequisites/Corequisites: Chemistry 222 or 231. No units.

Chemistry 390 — Independent Research *Fall, spring*
Involves an original and individual experimental investigation with associated literature study in one of the fields of chemistry under the supervision of a member of the faculty. The culmination of all research projects will be a report. The course is by permission only. Interested students are invited to apply before the registration period in the spring of the second or third year or the fall of the third or fourth year. The candidate's academic record will be reviewed to determine if the student could reasonably benefit form such a program. This course does not count toward the minimum number of chemistry courses required of the major. Prerequisites: Chemistry 222 and 231 or prior research experience at Holy Cross. One unit.

Chemistry 399 — Special Topics *Annually*
Courses explore various topics in chemistry. The subject and format varies with each offering. One unit.

Chemistry 405, 406 — General Research 1 and 2 *Fall, spring*
Involves an original and individual experimental and/or computational investigation with associated literature study in one of the fields of chemistry under the supervision of a member of the faculty. The culmination of all research projects will be a report, as well as an oral presentation to be given during the spring semester. Students will be required to attend the weekly department seminar program (fall and spring). Chemistry 405 is the first course of the consecutive two-semester research experience and carries no course credit; it is taken as an overload, on an "in-progress" basis. A grade will be given upon completion of Chemistry 406, which carries one and one-half units. Satisfactory completion of Chemistry 405 (including a poster presentation) is a prerequisite for Chemistry 406. Each course is by permission only. Interested students are invited to apply before the registration period in the spring of the second or third year. Application in the first year requires nomination by a faculty member. Taking Chemistry 405 in the spring semester requires approval of the Department Chair. The candidate's academic record will be reviewed to determine if the student could reasonably benefit from such a program. Prerequisites: Chemistry 222 and 231 or prior research experience at Holy Cross. One and one-half units.

Chemistry 407, 408 — General Research 3 and 4 *Fall, spring*
This program builds on the experiences gained in Chemistry 405 and 406. The second year of research provides the opportunity for further in-depth investigations. The culmination of all research projects will be a report and oral presentation to the chemistry faculty during the spring semester. Students will be required to attend the weekly departmental seminars program (fall and spring). Chemistry 407 is the first course of this consecutive two-semester research experience and carries no course credit; it is taken as an overload, on an "in-progress" basis. A grade will be given upon completion of Chemistry 408, which carries one and one-half units. Chemistry 408 can not be counted toward the required minimum number of chemistry courses. Satisfactory completion of Chemistry 407 (including a poster presentation) is a prerequisite for Chemistry 408. Both Chemistry 407 and 408 are by permission only. Interested students normally apply before the registration period in the spring of the third year. The candidate's academic record to date, with particular attention given to performance in Chemistry 405 and 406, will be reviewed to determine if the student could reasonably benefit from such a program. Prerequisites: Chemistry 405 and 406. One and one-half units.

Chemistry 410 — Advanced Research
This program builds on the experiences gained in prior research courses, providing the opportunity for further in-depth investigations. The culmination of all research projects will be a written report and a presentation to the chemistry faculty. Students will be required to attend the weekly departmental seminars program. This course is by permission only. Interested students normally apply to the department before the relevant registration period. The candidates academic record to date, with particular attention give to performance in prior research courses, will be reviewed to determine if the student could reasonably benefit form such a program. Prerequisites: Chemistry 390, 405/406 or 407/408. One and one-quarter units.