Chemistry at Dartmouth

2015-2016

Welcome to Burke Laboratory
Home of Dartmouth's Department of Chemistry

A Guide for the Prospective Chemistry Major

CHEMISTRY AT DARTMOUTH

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Introduction

Chemistry is the science of molecules. Chemists synthesize new drugs; they develop new polymeric, composite, and ceramic materials; they help in understanding and ameliorating environmental problems; and they work with medical teams to understand and cure human disease. More fundamentally, chemists want to know everything about molecules and their interactions with each other. Even when one looks outside of chemistry *per se* to the spectrum of forefront scientific research, including areas such as molecular genetics, alternative energy development, molecular biology, neurophysiology, molecular electronics, nutrition, and pharmacology, it is astonishing to see how much modern science depends on our ability to understand and manipulate molecules and their structures. Chemistry is an ancient discipline that evolved out of alchemy and natural philosophy, but it still seems to be at the center of most attempts to understand our immediate surroundings -- except that such an earthbound focus would ignore recent exciting discoveries about star formation in molecular clouds!

Chemistry majors and non-majors alike have opportunities at Dartmouth that are rarely found at other colleges and universities. Excellent teaching, close faculty-student relationships, and competitive research programs characterize the department. A small but highly regarded Ph.D. program and the presence of post-doctoral research associates help to insure a stimulating scientific atmosphere supported by modern research instruments that are accessible to undergraduates. The majority of such facilities are housed in Burke Laboratory.

In contrast to the practice at many other universities, Dartmouth faculty members normally teach all undergraduate courses. Graduate students and upper class undergraduates assist the faculty in laboratory teaching. During a student's first two years, honors courses are available in chemistry, mathematics, and physics for well-prepared and highly motivated students. These courses offer small class size, advanced level work, and especially close contact with faculty members. With Ethernet ports in each dorm room and wireless access throughout campus, computers play a major role in instruction at all levels. In the third or fourth year, chemistry majors have the opportunity to join a research group and pursue a project under the direct supervision of a faculty member. The more extensive of these research endeavors culminate in the writing of a senior Honors Thesis.

A student planning to major in chemistry designs a curriculum in consultation with a faculty advisor. During the first two years, all majors will complete a set of courses in chemistry, mathematics, physics, and possibly biology, selected according to the student's level of prior preparation, and the type of major they wish to pursue. All students without credit on entrance for introductory chemistry should plan to take either Chem 5 and 6, or Chem 10, noting that all of these courses have Math 3 as a prerequisite. All students should also take Math 8 (or equivalent), and those electing the plan A major will need to take Math 13 (or equivalent) as well. Students in all majors will be required to take an introductory physics sequence (13/14 or 3/4 or 15/16) – please note that physics at the level of Phys 13/14 is strongly preferred. Students in the Biological Chemistry major are required to take Bio 12

and Bio 13; Bio12 and Bio 13 are *recommended* for those in the Biophysical Chemistry track. During the final two years, upper level courses are chosen from those offered in chemistry and a variety of other disciplines to meet specific student interests, and to prepare for careers in chemistry, biochemistry, environmental science, medicine, law, or business. All chemistry major courses have associated laboratory instruction that not only illustrates basic principles, but also emphasizes modern techniques and student use of research-grade instruments.

The First Two Years

During the first and second years, all prospective majors elect a common core of courses in chemistry, physics, mathematics, and possibly biology. The specific choices, which depend on the level of preparation before entering Dartmouth and credit on entrance by Advanced Placement, and/or performance on departmental credit tests offered during First-Year Orientation, include a variety of regular and honors level courses. Possible paths through the major are given later in this brochure.

The usual first-year program for an entering student who is interested in chemistry includes Mathematics 3 (or the equivalent honors or higher-level mathematics course), which is the beginning course in calculus, during the fall term. Mathematics 3 (or credit on entrance) is a prerequisite and provides preparation for the general chemistry sequence, Chemistry 5-6, which a first-year student normally takes during the winter and spring terms (or fall-spring terms, if the student has credit on entrance for Mathematics 3). These courses serve as an introduction to modern chemical knowledge and the physical concepts used in its interpretation. The laboratory work emphasizes quantitative techniques and introduces the student to chemical instrumentation. Students who are less well prepared begin with Chemistry 2 in the fall term before enrolling in Chemistry 5.

A limited enrollment one-term honors general chemistry course, Chemistry 10, which is **open only to first-year students**, is offered in the fall, and covers selected general chemistry topics important for higher-level courses. Chemistry 10 also features a smaller class size than Chemistry 5- 6, greater depth of treatment of the subject matter, and a separate laboratory. Some background in chemistry is required, as is mathematics equivalent to Mathematics 3. Students with credit on entrance for both Chemistry 5 and Mathematics 3 are automatically eligible to be considered for admission into Chemistry 10. Students lacking credit on entrance for Chemistry 5, but who do have credit on entrance for Mathematics 3, may become eligible to be considered for admission into Chemistry 10 by a passing performance on a placement exam given during First-Year Orientation. Chemistry 10 is the prerequisite equivalent to Chemistry 5-6 for purposes of enrolling in higher-level courses.

In the second year, the prospective major begins the study of organic chemistry with either Chemistry 51-52 (offered as a fall-winter, or a spring-summer sequence) or Chemistry 57-58 (offered as a winter-spring sequence) Each sequence emphasizes both a theoretical approach to the subject as well as synthetic methods and mechanisms of organic reactions. In the organic chemistry laboratory, students have the opportunity to use equipment of research quality while learning the techniques of experimental organic chemistry.

The limited enrollment two-term honors organic chemistry sequence, Chemistry 57-58, is offered to students with a stronger interest in chemistry or with aspirations for a career in chemistry or a chemically related science. The goal is to make the Chemistry 57-58

laboratory work more challenging and research-oriented than that in Chemistry 51-52.

Increased competence in mathematics and physics is acquired in the first and second year through completion of the calculus sequence with Mathematics 8 and the general physics sequence, Physics 13-14 (strongly recommended) or Physics 3-4. Honors equivalents of these courses are also available. Prospective majors who have credit on entrance for Chemistry 5, or who take Chemistry 10 are strongly encouraged to take Physics 13 and 14 during their first year.

Advanced physical chemistry courses elected in the senior year may also require Mathematics 13. Biological Chemistry majors must also complete Biology 12 and 13.

Formal election of a major comes during the winter or spring term of the second year. At that time, a detailed plan for the third and fourth years is devised in consultations between the student and a chemistry faculty advisor. A general chemistry sequence, a general physics sequence, and a calculus sequence are prerequisites for a Plan A, Plan B, or Biophysical Chemistry major. For the Biological Chemistry major a biology sequence is also required. Beyond these courses, a minimum of eight upper-level courses, including two terms of organic chemistry, two terms of physical chemistry (one for the Biological major), and one term of inorganic chemistry are required in each major curriculum.

The Last Two Years

An element of the "Dartmouth Plan" is that almost all students are enrolled in courses during the summer term that follows the second year. (A corollary is that students do not enroll during one fall, winter, or spring term of either their second or third year.) The department offers Chemistry 63 (*Environmental Chemistry*) each summer as an opportunity for students to become educated about the many environmental problems that have a strong chemical component. In this course, students learn about topics such as depletion of stratospheric ozone, air pollution, global warming, pesticide use, and environmental carcinogens.

Four major curricula are described in detail below. The student who is interested in a career in chemical science will usually elect Plan A with its three physical chemistry courses, Chemistry 75 (*Physical Chemistry I*), Chemistry 76 (*Physical Chemistry II*) and Chemistry 96 (*Special Topics in Physical Chemistry*). Those with career goals outside chemical science *may* elect the Plan A major but often prefer the Plan B major. *Either* plan permits up to two advanced level courses from other science departments to be included in the eight courses of the major. The Biophysical Chemistry major is available for those students who desire a program in biochemistry with a strong background in chemistry. This program is intended to prepare students for admission to top graduate programs in fields with a variety of disciplinary titles, such as chemistry, biochemistry, molecular biology, biophysics, and structural biology. Finally, it is important to note that all three majors have required courses that are offered in the winter and spring terms. The Plan A and Biophysical Chemistry majors require that at least one major course be taken in each of the winter and spring terms of the third year, and students should plan to be in residence these terms, in addition to their fourth year. Although, the Plan B major is more flexible, scheduling of major courses will be easier if two major courses are elected in the third year. The fourth program is a major in biological chemistry. This major is designed for students interested in applications of chemistry to fundamental biological

processes, similar to the biophysical chemistry option, but without as much emphasis on the physical chemical underpinnings. The Biological Chemistry major requires that both Chemistry 40 and 41 be completed by the end of the junior year, so that Chemistry 42 can be taken in senior fall. In addition to being suitable for premedical students, it provides the framework for further graduate study in all areas of biological chemistry and biomedicine.

It is important to note that planning the Chemistry major course sequence should be done carefully, with the advice from a faculty member of the Undergraduate Advisory Committee. This is particularly true in the context of deciding which term to be away from campus during the sophomore or junior year.

Plan A Major

The core Plan A curriculum requires Chemistry 51 (or 57) and 52 (or 58) *(Organic Chemistry),* Chemistry 64 (*Inorganic Chemistry*), Chemistry 75 (*Physical Chemistry I*), Chemistry 76 (*Physical Chemistry II*), and Chemistry 96, a special topics course, with offerings normally at least twice a year from among Quantum Chemistry, Statistical Thermodynamics, Molecular Spectroscopy, Physical Chemistry of Polymers, Introduction to Materials Science, and Chemical Kinetics. Chemistry 75 and 76 provide a strong curriculum that covers all major aspects of thermodynamics, kinetics, transport processes, quantum mechanics, and molecular spectroscopy. A study of advanced topics in the above areas, and/or additional topics is provided in Chemistry 96. Chemistry 75 and 76 are best taken in the winter and spring terms, respectively, of the third year, and Chemistry 96 would then be elected in the senior year. Chemistry 64, which is offered in the winter term and has Chemistry 51 (or 57) as prerequisite, may be taken in the second, third or fourth year.

Laboratory work in Chemistry 64 emphasizes the synthesis, characterization, and spectroscopy of inorganic molecules. Laboratory work in Chemistry 75 and 76 illustrates concepts covered in the classroom and makes extensive use of instrumental techniques. Chemistry 76 also involves a computational laboratory.

The Plan B Major

The core curriculum of the somewhat more flexible Plan B major requires Chemistry 51 (or 57) and 52 (or 58) (*Organic Chemistry*), Chemistry 64 (*Inorganic Chemistry*), Chemistry 75 (*Physical Chemistry I*, and Chemistry 76 (*Physical Chemistry II*). Chemistry 64, which is offered in the winter term, and has Chemistry 51 (or 57) as prerequisite, may be taken in the second, third or fourth year. Chemistry 75 (offered in the winter term) and Chemistry 76 (offered in the spring term) may be taken in either the third or fourth year. This two-term physical chemistry sequence covers the major topics of thermodynamics, kinetics, transport processes, and the application of quantum mechanics to bonding and spectroscopy.

Biophysical Chemistry

The core curriculum of the Biophysical Chemistry major requires Chemistry 51 (or 57) and 52 (or 58) *(Organic Chemistry),* Chemistry 41 *(Biological Chemistry I),* Chemistry 64 *(Inorganic Chemistry),* Chemistry 75 *(Physical Chemistry I)* or Chemistry 40 (*Physical Chemistry of Biochemical Processes*), Chemistry 76 *(Physical Chemistry II)*, and Chemistry 67 (*Physical Biochemistry*). Chemistry 75 (or Chemistry 40) and 76 are best taken in the winter

and spring terms, respectively, of the third year, and Chemistry 67 should be taken in winter term of the senior year. Chemistry 64, which is offered in the winter term, and has Chemistry 51 (or 57) as prerequisite, may be taken in the second, third or fourth year. The one-term introduction to biochemistry, Chemistry 41, is taken either in the spring term of the second year, right after completion of organic chemistry (Chemistry 52), or in the spring term of the third year along with Chemistry 76. Additional elective courses offered in this area include Chemistry 42 (*Biological Chemistry II*) in the fall term, and Chemistry 161, a special topics course, with offerings at least once a year from among Membrane Biophysics, Biomolecular Simulations, Biomolecular NMR, Structure and Dynamics of Biomolecules, and Protein Crystallography.

Biological Chemistry

The core curriculum of the Biological Chemistry major requires Chemistry 51 (or 57) and 52 (or 58) *(Organic Chemistry),* Chemistry 64 *(Inorganic Chemistry),* Chemistry 40 *(Physical Chemistry),* Chemistry 41 and Chemistry 42 *(Biological Chemistry).* Additional courses needed to make up the requisite eight are listed in the ORC or on the Chemistry Department website. *At least one of the additional courses must have a biochemical focus*.

All Chemistry Majors

All majors in chemistry are completed by the election of additional chemistry courses during the second, third and fourth years. Of particular note is the opportunity to participate in undergraduate research by electing one or more terms of Chemistry 87, as discussed below.

Chemistry faculty also teach a number of senior undergraduate/first-year graduate courses that are available to qualified undergraduates and allow a specialized, advanced curriculum, once required major courses are completed. Some examples of such courses that have been elected by chemistry majors include the various versions of Chemistry 96 (*Quantum Chemistry, Statistical Thermodynamics, Molecular Spectroscopy, Physical Chemistry of Polymers, Introduction to Materials Science, and Chemical Kinetics*), Chemistry 90 (*Organometallic Chemistry*), Chemistry 91 (*Advanced Inorganic Chemistry: Catalysis*), Chemistry 92 (*Inorganic Biochemistry*), Chemistry 93 (*Physical Organic Chemistry*), Chemistry 152 (*Advanced Organic Synthesis and Mechanisms*), Chemistry 153 (*Chemistry of Natural Products*), Chemistry 159 (*Chemistry of Heterocyclic Compounds*), and Chemistry 161 (*Membrane Biophysics, Biomolecular Simulations, Biomolecular NMR, Structure and Dynamics of Biomolecules, and Protein Crystallography*). Please see the ORC for a complete list of upper level courses that are offered.

In keeping with the Department's desire to make the chemistry major adaptable to a wide spectrum of student interests, two of the courses for Plan A and B majors (one for Biophysical or Biological Chemistry majors) comprising an eight course major may be selected from among a number of courses outside the Department. These include Physics 19 *(Introductory Physics III),* Biology 40 *(Biochemistry)* for Plan A and B majors who are not taking Cheistry 41, Mathematics 20 *(Discrete Probability),* Mathematics 22 (or 24) *(Linear Algebra),* Mathematics 23 *(Differential Equations)* and Mathematics 46 *(Introduction to Applied Mathematics).* With departmental permission, other advanced undergraduate or graduate courses in the science division can also be elected for major credit.

Some Possible Paths through the Chemistry Major

All Chemistry major tracks require at least 8 major courses, together with a culminating experience. (For all the options described below, the culmination requirement could be satisfied by participating in Undergraduate Research)

Some options that do NOT require taking two major courses in a term

Year/Term	Fall	Winter	Spring	Summer
Two	51	52	41	63
Three		64	(90) or (92)	
Four	(91) or (93)	75	76	

Suitable for the Plan B major. Only one of the four courses shown in parentheses would be required for the minimum of 8 courses. The culminating experience course option is 63, 64, and one of 90, 91, 92, or 93.

Year/Term	Fall	Winter	Spring	Summer
Two	51	52	41	63
Three		75	76	
Four	(96.x) or (93)	64	(90) or (92)	

Suitable for Plan A or Plan B. Only one of the four courses shown in parentheses would be required for the minimum of 8 courses. The culminating experience course options are 63, 64, and one of 90, 92, or 93 (Plan B); or 75, 76, 96.x (Plan A).

Year/Term	Fall	Winter	Spring	Summer
Two		57	58	63
Three		75	76	
Four	(96.x) or (93)	64	(41) or (90) or (92)	

Suitable for Plan A or Plan B. Only two of the five courses shown in parentheses would be required for the minimum of 8 courses. The culminating experience course options are 63, 64, and one of 90, 92, or 93 (Plan B); or 75, 76, 96.x (Plan A).

Year/Term	Fall	Winter	Spring	Summer
Two		57	58	63
Three		64	(41) or (90) or (92)	
Four	(91) or (93)	75	76	

Suitable for the Plan B major. Only two of the five courses shown in parentheses would be required for the minimum of 8 courses. The culminating experience course option is 63, 64, and one of 90, 91, 92, or 93.

Year/Term	Fall	Winter	Spring	Summer
Two	51	52	41	63
Three		75		
Four	93 or 96.4	64	76	

Suitable for Plan B. The culminating experience course option is 63, 64, and 93. (96.4 does not require 76)

Year/Term	Fall	Winter	Spring	Summer
Two		57	58	63
Three		75	41	
Four	93 or 96.4	64	76	

Suitable for Plan B. The culminating experience course option is 63, 64, and 93. (96.4 does not require 76)

Year/Term	Fall	Winter	Spring	Summer
One	10 or 6	57	58	
Two	(93)	64	41	63
Three		75	76	
Four	(91) or (93) or (96.x)	(67)	(90) or (92) or (161.x)	

This plan requires credit on entrance for Mathematics 3 and Chemistry 5.
Suitable for Plan A, B, or Biophysical. Only one of the eight courses shown in parentheses would be required for the minimum of 8 courses. The culminating experience course options are 75, 76, 96.x (Plan A); or 63, 64, and one of 90, 91, 92, or 93 (Plan B); or 75, 76, 67 (Biophysical).

Some options that require taking two major courses in just ONE term

Year/Term	Fall	Winter	Spring	Summer
Two			51	52, 63
Three		75	76	
Four	(93) or (96.x)	64	(41) (90)	

Suitable for Plan A or Plan B. Two of the four courses shown in parentheses would be required for the minimum of 8 courses. The culminating experience course options are 63, 64, and one of 90 or 93 (Plan B); or 75, 76, 96.x (Plan A).

Year/Term	Fall	Winter	Spring	Summer
Two		57	58	63
Three		75	41, 76	
Four	(93) or (96.x)	64	(90) or (92)	

Suitable for Plan A or Plan B. One of the four courses shown in parentheses would be required for the minimum of 8 courses. The culminating experience course options are 63, 64, and one of 90 or 92 or 93 (Plan B); or 75, 76, 96.x (Plan A)

Year/Term	Fall	Winter	Spring	Summer
Two			51	52, 63
Three		64	41	
Four	(91) or (93)	75	76	

Suitable for Plan B. One of the two courses shown in parentheses would be required for the

minimum of 8 courses. The culminating experience options are 63,64, and one of 91 or 93.

Some options for the Biophysical Chemistry major

Year/Term	Fall	Winter	Spring	Summer
Two	51	52	41	(63)
Three		64 and 75 (or 40)	76 and (90) or (92)	
Four	(91) or (93) or (96.x)	67	(90) or (92)	

Only one of the five 90-level courses shown in parentheses would be required for the minimum of 8 courses. The culminating experience course options are 75, 76, 96.x; or 75, 76, and 67; or 63, 64, and one of 90, 91, 92 or 93.

Year/Term	Fall	Winter	Spring	Summer
Two	51	52		(63)
Three		64 and 75 (or 40)	41 and 76	
Four	(91) or (93) or (96.x)	67	(90) or (92)	

Only one of the five 90-level courses shown in parentheses would be required for the minimum of 8 courses. The culminating experience course options are 75, 76, 96.x; or 75, 76, 67; or 63, 64, and one of 90, 91, 92 or 93.

Year/Term	Fall	Winter	Spring	Summer
Two		57	58	(63)
Three		64 and 75 (or 40)	41 and 76	
Four	(91) or (93) or (96.x)	67	(90) or (92)	

Only one of the five 90-level courses shown in parentheses would be required for the minimum of 8 courses. The culminating experience course options are 75, 76, 96.x; or 75, 76, and 67; or 63, 64, and one of 90, 91, 92 or 93.

Representative schedule of courses for Biological Chemistry majors

1. No Chemistry or Mathematics credits on entrance:

Year/Term	Fall	Winter	Spring	Summer
First	Math 3	Chem 5 Math 8	Chem 6 Bio 12††	
Sophomore	Chem 51† Phys 13	Chem 52†	Phys 14	[Chem 63]* Bio 13
Junior		Chem 40† Chem 64†	Chem 41†	
Senior	Chem 42†	[Chem 67]*	[Chem 161]* [Chem 92]*	

† Required for major (6)

†† Students may wish to take Bio 11 before taking Bio 12

* *Possible additional courses (2 needed for major-at least 1 must have a biochemical focus)*

2. Credits on entrance for Math 3 and Chem 5 (or placement into Chem 10):

Year/Term	Fall	Winter	Spring	Summer
First	Chem 6 *or* 10 Math 8 *or* 11	Phys 13	Bio 12†† Phys 14	
Sophomore	Chem 51†	Chem 52† Bio 13	Chem 41†	[Chem 63]*
Junior		Chem 40† Chem 64†		
Senior	Chem 42†	[Chem 67]*	[Chem 161]* [Chem 92]*	

† Required for major (6)
* *Possible additional courses (2 needed for major-at least 1 must have a biochemical focus)*
†† Students may wish to take Bio 11 before taking Bio 12

Year/Term	Fall	Winter	Spring	Summer
First	Chem 6 *or* 10 Math 8 *or* 11	Phys 13	Bio 12†† Phys 14	
Sophomore		Chem 57† Bio 13	Chem 58†	[Chem 63]*
Junior		Chem 40† Chem 64†	Chem 41†	
Senior	Chem 42†	[Chem 67]*	[Chem 161]* [Chem 92]*	

† Required for major (6)
* *Possible additional courses (2 needed for major-at least 1 must have a biochemical focus)*
†† Students may wish to take Bio 11 before taking Bio 12

For other options, please see:
www.chemistry.dartmouth.edu/undergraduate/major/planning_for_a_chemistry_major_2015.pdf

The Department's Undergraduate Advisory Committee (UAC) is always available to help you find the path best suited for you.

The Culminating Experience

Dartmouth College requires that all majors must complete a substantial, graded culminating or integrating activity in their major. Many Plan A, B, Biophysical, or Biological chemistry majors will satisfy this requirement by participating in undergraduate research by registering for one or more terms of Chemistry 87 (*Undergraduate Investigation in Chemistry*). Often such students will be enrolled in the Chemistry Honors Program as well. Please note that the College's minimum requirement for admission to the Honors Program is a grade point average of 3.0 in the major and a 3.0 general College average at the beginning of the senior year or at any other time that an application for admission is made.

Other chemistry majors will satisfy the requirement for a culminating or integrating experience by including in their major programs one of the following course groups, each of which provides an integrated presentation of an important area of modern chemical sciences: *Biophysical Chemistry*: Chemistry 75 (or 40), 76 and 67;

Biological Chemistry: Chemistry 40, 41 and 42; *Physical Chemistry*: Chemistry 75, 76 and 96; or *Chemical Applications, Synthesis and Characterization:* Chemistry 63, 64, and one course from among Chemistry 90, 91, 92, and 93. Note that for Biological Chemistry majors, Chemistry 40, 41 and 42 is a required sequence.

Students must be prepared to discuss their plans for satisfying the requirement for the culminating or integrating experience at the time they enroll in the major. Since a student may not enroll in Chemistry 87 until after they have been accepted into the Chemistry 87 Program, the initial declaration of a major will satisfy the culminating experience requirement using one of the three-course groups mentioned above. In addition they must confirm their major plans at the beginning of the fall term of the fourth year.

The four-term, year-round operation of the College requires careful planning of the major program in consultation with a chemistry faculty advisor but permits some flexibility in the individual curricular plan and attendance pattern. Vacation term opportunities may include research and teaching assistantships at Dartmouth or elsewhere, and industrial or government jobs or internships. Information and assistance are available through the Department and the College's Office of Career and Employment Services. The Department also hires many of its majors for part- time positions such as laboratory teaching assistant, or stockroom assistant.

The Chemistry Minor

The Chemistry Department offers a single minor program. The minimum prerequisites for the minor are Mathematics 3 (or the equivalent) and two terms of introductory chemistry (three terms if you are placed into Chemistry 2); Chemistry 5 and 6, *or* 10 are suitable for this purpose. Four additional courses are required for the minor and must include Chemistry 51 or 57 (*Organic Chemistry*) and Chemistry 64 (*Inorganic Chemistry*). The remaining two courses may be selected from other chemistry courses numbered 40 or higher. The NRO option is disallowed for courses taken to fulfill the chemistry minor.

In addition, the Chemistry Department, together with Physics and Engineering, jointly sponsors a minor in Material Science. This minor program is coordinated through the Center for Nanomaterials Research at Dartmouth.

Modified Majors

For individuals with special interests, modified majors in which chemistry is combined with such disciplines as biology, earth sciences, mathematics, physics, or environmental studies can be arranged. At Dartmouth, the course requirements for a modified major are proposed by the student and, subject to institutional guidelines, approved by the departments or programs involved. In addition to modified majors with chemistry and a second science, recent examples of creative curriculum planning have included modified majors in chemistry and psychology, chemistry and religion, and chemistry and economics. Dartmouth's guiding principle is that a modified major, however diverse, must constitute a "unified and coherent whole." As part of the application process, each student must submit a written statement documenting why he or she believes the proposed modified major meets that requirement.

Undergraduate Research

Research Opportunities for Upper Class Students

For students who are interested in research, the department offers Chemistry 87 as a course in which individual investigations are carried out under the supervision of a faculty member. Included are an initial literature study of the problem, the experimental, computational or theoretical research, and a detailed report upon completion of the project. Chemistry 87 normally is elected for more than one term and, although it can be counted only once toward the eight course major requirement, each election (up to a maximum of three) counts towards the College's graduation requirements. Often, the faculty is able to offer extra-curricular opportunities to do research, and undergraduates may be able to work full-time on a research project during leave on vacation terms. Sometimes students are successful in winning Zabriskie, Waterhouse, or Richter grants to help with their expenses while they are engaged in full-time research. Moreover, sometimes faculty members are able to provide financial support from research grants.

Research interests of the faculty are described below:

- Organic and materials chemistry: Self-assembly; supramolecular interactions; molecular switches and machines; nanotechnology — **Professor Ivan Aprahamian**

- Physical chemistry and materials: computational chemistry, molecularly imprinted polymers, nanoparticle properties, laser spectroscopy, multiphoton mass spectrometry — **Professor J. J. BelBruno**

- Biophysical chemistry: theoretical investigations of the relation between cell membrane composition and the activity of membrane proteins, with application to the molecular mechanisms of anesthesia — **Professor R. S. Cantor**

- Physical chemistry: theoretical calculations of the properties of molecules in external magnetic and electric fields; computational studies of carbocation-π complexation — **Professor R. Ditchfield**

- Organic, organometallic and inorganic chemistry: homogeneous catalysis, asymmetric synthesis, chiral phosphines, sustainable energy — **Professor D. S. Glueck**

- Organic chemistry: synthesis of biologically active natural products, with emphasis on indole alkaloids, triterpenoids, and heterocycles; new synthetic methods; novel heterocyclic compounds; cancer chemopreventive agents — **Professor G. W. Gribble**

- Organic chemistry: total synthesis of natural products, new synthetic methods, molecular rearrangements, heterocyclic chemistry — **Professor P. A. Jacobi**

- Supramolecular chemistry: carbohydrate recognition — **Professor C. Ke**
- Biophysical chemistry: X-ray crystallographic, biophysical, and kinetic characterization of molecular motors, cytoskeletal-associated nucleotide hydrolases,

and structural proteins; force generation in biological systems; enzyme kinetics; protein engineering — **Professor F. J. Kull**

- Computational materials and polymer physical chemistry: theoretical and computational studies of the behavior of polymer solutions, melts and blends; glassy materials and thin films; aging in films and glasses — **Professor J. E. G. Lipson**

- Organic Synthesis —**Professor G. C. Micalizio**

- Biophysical chemistry: structural basis of the biological function of peptide hormones and regulation/trafficking of their receptors; structure-based rational drug design employing experimental (NMR, fluorescence, circular dichroism) and theoretical (molecular dynamics, docking) methods — **Professor D. F. Mierke**

- Design synthesis of selective gas sensors — **Professor K. A. Mirica**

- Biophysical chemistry: protein dynamics, cell signaling and laser spectroscopy, NMR — **Professor E. Pletneva**

- Protein crystallography, small angle x-ray scattering, peripheral membrane proteins, autophagy — **Professor M. Ragusa**

- Inorganic and bioinorganic chemistry: reactions and spectroscopy of transition metal ions; coordination chemistry of proteins and peptides, thermodynamics of metal ions binding and stabilizing biological macro molecules — **Professor D. E. Wilcox**

- Physical chemistry: molecular beam spectroscopic and collisional studies of elementary processes, energy exchange, and weakly bound molecules; elucidation of the intermolecular forces governing these situations; matrix isolation spectroscopy — **Professor J. S. Winn**

- Organic Chemistry: development of new methods in enantioselective catalysis particularly in asymmetric organocatalysis and the total syntheses of complex natural products — **Professor J. Wu**

Listed below are the titles of some recent honors theses, and research reports along with the name and graduating class of the student authors:

Michelle Chen ’15	Ionic Liquids: Modeling Trends in Pure Solvent Properties and Miscibility with Polymers (Jane E.G. Lipson)
Mizuho Horioka ’15	Study of the Stabilisation of the Insulin Hexamer by the Surrogate Metal Ion (Co^{2+}) using Isothermal Titration Calorimetry (Dean Wilcox)
Eileen Jin ’15	The Production of Molecularly Imprinted Polymers for the Removal of Guaiacol from Wine (Gordon Gribble)

Eliana Eunhee Kim ’15	Synthesis of Novel 3-Alkyl-2-Hydroxy-1,4-Naphthoquinone Derivatives: A Series of Potential Anti-Malarials (Gordon Gribble)
Jonathan M. King ’15	Computation Analysis of Doped II-VI Nanoclusters (Joseph BelBruno)
Emily M. Lacroix ’15	Organo-mineral binding of soil organic matter in the northeastern U.S.: the long-term effects of logging (Andrew J. Friedland)
Martin Tomanik ’15	Synthesis of GLP-1 Secretagogues Utilizing Indole (4+3) and (3+2) Annulation Reactions (Jimmy Wu)
Brendan Wang ’15	Computational Study of Doped Zinc Sulfide Structures: Clusters and Nanotubes (Joseph BelBruno)
Rebecca S. Xu ’15	Synthesis of Air-Stable Chiral Phosphines from (+)-Limonene Oxide (David Glueck)
Saara-Anne Azizi ‘14	Light-activated manipulation of liquid crystals using BF2-azo complex (Ivan Aprahamian)
Alan Chou ‘14	Analysis of Glycosylated Variants of Antithrombin for Treatment of Sepsis (Nicholas Shworak)
David Clemens-Sewall ‘14	Novel Trinuclear Copper(I) Pyrazolates Displaying Aurophilic Interactions (David Glueck)
Laura Cressman ‘14	Synthesizing a Molecular Imprinted Polymer to Detect Vitamin D3 (Joseph BelBruno)
Meaghan Deegan ‘14	Enantioselective synthesis of syn-phosphiranes (David Glueck)
Alexandra Khitun ‘14	Thermodynamics of Metals Binding to Merlyase (Dean Wilcox)
Easha Narayan ‘14	Synthesis of Pyrrole Pyrimidines-New Biological Targets (Gordon Gribble)
Jesse Peltier ‘14	Toward Selective Mono-Benzylation of 1, 2-Bis(phenylphosphino)ethane (David Glueck)
Christopher Price ‘14	A Theoretical Study of the Glass Transition in Polymer Films (Jane Lipson)
Michael Seitz ‘14	Producing a Specific Recombinant Lentivirus that Expresses siRNA against the Lipid Exporter ABCA1 (Ta Yuan Chang)

Ryan Tibble '14	Characterization of the kinesin-related protein Costal2 (F. Jon Kull)
Karen Wai '14	Regulation of MDM2 and HUWE1 Interaction (Marabu Kurokawa)

Honors Program

The Chemistry Honors Program involves the writing of a thesis based on original experimental, computational or theoretical research. Students whose grades meet the minimum College GPA requirement for honors work (3.0 in the major and a 3.0 general College average) may arrange with a faculty member to undertake a project under their supervision and apply for admission to the program. The Chemistry Honors Program may be completed by electing Chemistry 87 (*Under graduate Investigation)* for academic credit three times, or by a schedule designed such that the cumulative research effort is the equivalent of three terms of Chemistry 87. Such schedules often involve combinations of Chemistry 87, research in a leave term, and part-time research conducted while enrolled in three other courses. On completion of the work, the student will write a thesis and take an oral examination. The program is open to qualified seniors and advanced juniors.

Integrated 4+1 AB/MS Program in Biophysical Chemistry

The Department offers a 4+1 program to provide Dartmouth undergraduate students with an opportunity to acquire a broader and deeper education in modern techniques of biophysical chemistry through a combination of coursework and independent research under the direction of one of the program faculty. By integrating undergraduate courses and a substantial independent research effort during the senior year, the MS can be obtained in one year directly after completing the AB at Dartmouth (generally in Biophysical Chemistry). Interested students should contact Professor Dale F. Mierke no later than the beginning of winter term of the junior year.

Advising

The Department's Undergraduate Advisory Committee (UAC), as well as members of the Chemistry faculty assists students in planning their major, selecting graduate schools and in making other career choices. For those going on in medicine, a faculty member often writes the composite letter of recommendation for medical schools.

Career Opportunities

Students majoring in chemistry have a wide variety of careers available to them:

Chemistry. The Department receives information and advises students regarding graduate study in chemistry and jobs in industry or government upon graduation. A placement service maintained by the College is available to all students.

Medicine. Many students use a major in chemistry as a rigorous basis for medical studies leading to a career in medical practice or research. It should be noted, however, that medical schools do not require chemistry or other science majors, and many future medical students complete a major outside of the sciences.

Biochemistry. Students interested in biochemistry can choose to major in Biophysical Chemistry in the Chemistry Department or Biochemistry and Molecular Biology offered by the Biology Department. Both routes provide a suitable basis for graduate study in biochemistry or molecular biology.

Environmental Science. Majors can use courses from the Environmental Studies Program to relate chemistry and other sciences to environmental problems. Other environmental studies courses relate the science to policy formulation, education, and public action. Students have used such backgrounds as preparation for graduate work in environment and natural resource programs, as well as for immediate employment with consulting companies and public interest organizations.

Secondary School Teaching. Students interested in a career in secondary school teaching will supplement or modify their major with suitable courses in education, including a term of practice teaching.

Engineering, Business, and Law. An occasional chemistry major goes on to graduate study in engineering or in fields outside of science, such as business administration or law, in which training in a scientific discipline can lead to special opportunities. Chemists sometimes serve as members of teams dedicated to research, planning, and services in many fields of human activity.

Chemical Engineering. The student interested in chemical engineering should consult at the earliest opportunity with members of the Chemistry and Thayer School (engineering) faculties regarding suitable programs.

Facilities and Programs

The undergraduate major receives many benefits from our competitive graduate program and from new initiatives in material science (The Center for Nanomaterials Research at Dartmouth) and structural biology. Research in the general fields of inorganic, organic, physical, theoretical and biological chemistry is supported by modern instrumentation, computers and a first-rate library, including computer-assisted literature searches. Almost all of the research laboratories are located in a state-of-the-art chemistry facility, Burke Laboratory. All majors are welcome to attend the weekly departmental colloquium, which features speakers from other universities and from industry. Undergraduate research students also attend the research seminars of their research group. Graduate courses allow advanced undergraduates to pursue specific interests as these develop. Chemistry faculty members are pleased that the Department ranks at or near the top in undergraduate evaluation of teaching quality at Dartmouth. We believe we have one of the best undergraduate programs in chemistry available at any college or university.

Some Statistics for the Department of Chemistry

Teaching Faculty	19
Research Faculty	5
Adjunct Faculty	6
Visiting Faculty	1
Chemistry Major/Minors graduating yearly	23 (on average)
Ph.D. Degrees each year	5-8 (on average)
Research Associates (Post Docs) each year	12 (on average)

Major Research Equipment

(all available for hands-on use by qualified undergraduates)

Three Nuclear Magnetic Resonance (NMR) Spectrometers, including Varian 300 MHz Varian 500 MHz instruments, and 600 MHz Bruker Avance III

Gas Chromatography/Mass Spectrometers

Electron Paramagnetic Resonance Spectrometer

Fourier Transform Infrared (FTIR) Spectrometers, including a high-resolution Bomem instrument

Excimer, YAG, and Nitrogen Pumped Dye Lasers

Laser Transients Absorption Spectrometer Isothermal

Titration Calorimeters

Circular Dichroism Spectrophotometer

UV/Visible/NIR Spectrophotometers

Ultracentrifuges

Gas Chromatographs

Differential Scanning Calorimeters

High Performance liquid Chromatographs

Cryogenic Matrix Isolation Apparatus

If you have any questions, please feel free to contact:

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