A new option for the chemistry major: Biological Chemistry

A significant number of students at Dartmouth are very interested in biological chemistry and would be strongly attracted to a major that reflects that interest. Although our Biophysical Chemistry option is appealing, many are reluctant to invest the considerable time and effort required to take two terms of general physical chemistry before being exposed to some of the important biological applications covered in Chem 67. However, a somewhat abbreviated introduction to physical chemistry that focuses *exclusively* on applications to biological processes might be much more attractive.

So, to provide these students with an undergraduate program more closely aligned with their interests, a new option for the major, named "Biological Chemistry" has recently beenapproved, and will be implemented beginning with the current sophomore class (2014). To that end, a new course has been created -- Chem 40 -- designed to introduce students to the subset of concepts and techniques of physical chemistry most essential for the understanding of fundamental biological processes. Chem 40 differs substantively from a standard introductory Physical Chemistry course in that it does *not* provide a general overview; rather, the selection of topics (and the amount of time devoted to each) reflects their relative importance and applicability to fundamental biochemical processes. Chem 40 will be offered in the Winter term, starting next year (2013).

In concert with Chem 40, the content of Chemistry 42 will be adjusted: it would serve not only to continue the discussion of topics in biochemistry not covered in Chem 41, but would follow Chem 40 in presenting the physical underpinnings, particularly involving quantum mechanics and spectroscopy. Thus, both Chem 40 and Chem 41 (Biological Chemistry I) would serve as prerequisites for Chem 42. *Chem 40, 41 and 42 would all be required for, and indeed form the culminating experience of the Biological Chemistry major.*

Our current Biophysical Chemistry majors take the Chem 75/76 physical chemistry sequence, followed by physical biochemistry (Chem 67), for which Chem 76 and 41 are prerequisite. The combination of Chem 40 and 42 will provide sufficient mastery of the fundamental physical chemistry to serve alternatively as a prerequisite for 67. Thus, Biological Chemistry majors who have completed Chem 42 would be permitted to enroll in Chem 67, which would be a recommended elective (but not required) for the Biological Chemistry major.

The current (online) version of the ORC does not yet include a description of the new Biological Chemistry major, nor any of the related changes to the course listings. An updated version of the Course Descriptions and the Departmental Requirements for the Chemistry major can be found in the accompanying documents; changes from the current edition are indicated in **boldface**.

There is considerable flexibility in developing a schedule to satisfy the course requirements for the Biological Chemistry major; on the following page are provided two representative examples. Questions about this or any other aspect of the major should be addressed to the faculty members

of the Undergraduate Advising Committee in Chemistry (Professors Ditchfield, Gribble (Chair), Kull, and Lipson).

Representative schedule of courses for Biological Chemistry majors:

1. No prematriculation credits:

	Fall	Winter	Spring	Summer
Fresh	Chem 8 *or* Bio 11 Math 3	Chem 9 *or* 5 Math 8	Chem 6 Bio 12	
Soph	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 87]*	[Chem 161]* [Chem 92]*	

† Required for major (6)

* *Possible additional courses (2 needed for major)*

2. With prematriculation credit for Math 3 and Chem 5 (or placement into Chem 10):

	Fall	Winter	Spring	Summer
Fresh	Chem 6 *or* 10 Math 8 *or* 11	Bio 11 Phys 13	Bio 12 Phys 14	
Soph	Chem 51†	Chem 52† Bio 13		[Chem 63]*
Junior		Chem 40† Chem 64†	Chem 41†	
Senior	Chem 42†	[Chem 67]* [Chem 87]*	[Chem 161]* [Chem 92]*	

† Required for major (6)

* *Possible additional courses (2 needed for major)*

ORC: Course Descriptions for the Chemistry Department

2. Quantitative Reasoning in Chemistry

11F, 12F: 10

A course for students who intend to take Chemistry 5-6, but who need additional preparation for quantitative and analytical aspects of general chemistry. Chemistry 2 develops the quantitative basis of chemistry relationships and the skills to solve chemistry problems. Much of the course will be devoted to mathematical manipulations and functional relationships that are integral to the quantitative applications of chemistry concepts. In-class experiments will introduce the analysis, interpretation and presentation of chemical data. Students are placed into Chemistry 2 based on their pre-matriculation mathematics and science record. *Dist: SCI*.

5-6. General Chemistry

5. 11F: 10 12W: 9L, 10 12F: 10 13W: 9L, 10; Laboratory: Arrange

6. 11F: 9L 12S: 9L, 10 12F: 9L 13S: 9L, 10; Laboratory: Arrange

An introduction to the fundamental principles of chemistry, including chemical stoichi-ometry; the properties of gases, liquids, and solids; solutions; chemical equilibria; atomic and molecular structure; an introduction to thermodynamics; reaction kinetics; and a dis-cussion of the chemical properties of selected elements. The laboratory work emphasizes physical-chemical measurements, quantitative analysis, and synthesis.

An outline of topics for review of secondary school background in preparation for college general chemistry is available from the Department of Chemistry.

Students who are eligible to receive advanced placement credit for Chemistry 5-6 may not enroll in Chemistry 5-6 or Chemistry 10 for credit without permission of the Depart-ment. Advanced placement credit for Chemistry 5-6 will be withdrawn for students who subsequently enroll in Chemistry 5-6 or Chemistry 10. Students with credit for Biology/Chemistry 9 may not enroll in Chemistry 5.

Prerequisite for Chemistry 5: Mathematics 3, *or* Mathematics 1 and 2, *or* Mathematics 1 and Chemistry 2. (First year students taking Mathematics 1 will be placed in Chemistry 2). Prerequisite for Chemistry 6: Mathematics 3 (or Mathematics 1 and 2) *and* Chemistry 5 or Biology/Chemistry 9.

Supplemental course fee required. *Dist: SLA*.

7. First-Year Seminars in Chemistry

Consult special listings

8-9. Chemical Principles and Biological Processes I &II (*Identical to Biology 8-9*)

8. 11F, 12F: 10A; Laboratory: Arrange

9. 12W, 13W: 10A; Laboratory: Arrange

This two-term course will cover principles and processes of general chemistry as applied to biochemistry and cell biology. Over the course of two terms, students will receive an introduction to the fundamental principles of chemistry (matter, elements, atoms, equilibria, acids and bases, enthalpy, thermochemistry, entropy, free energy, redox reactions, and electrochemistry) in the context of fundamental biological processes and systems (biopolymer structure, protein folding and denaturation, membranes and transport, receptor/ligand binding, metabolism and energy production). Upon completion of both Chemistry 8 *and* 9, students will have fulfilled the prerequisites necessary for entry into Chemistry 6 and any of the foundation level courses in Biology (Biology 12-16). Successful completion of only the first term (Biology/ Chemistry 8) will result in a SCI distributive credit but will not fulfill any prerequisite requirements.

Biology 8 and 9 are the same as Chemistry 8 and 9. For simplicity, and for clarity with respect to medical school applications, upon completion of this two-term sequence the student transcript will show Biology 8 and Chemistry 9, regardless of how students elected these courses at the time of registration.

Enrollment is limited to 80 students. *Dist: Biology/Chemistry 8, SCI; Biology/Chemistry 9, SLA*

Students who have received credit for Chemistry 5 taken at Dartmouth, or received transfer credit for Chemistry 5, may not enroll in Biology/Chemistry 8. Students who have received pre-matriculation credit for Chemistry 5 may not enroll in Biology/Chemistry 8 without permission of the Chemistry Department. Pre-matriculation credit for Chemistry 5 will be withdrawn for students who subsequently enroll in Biology/Chemistry 8. Students who receive credit for Biology/Chemistry 9 may not subsequently enroll in Chemistry 5.

Pre-health students who complete Biology/Chemistry 8-9 will have fulfilled the following with respect to the pre-health requirements: one term of general chemistry with lab, and one term of general biology with*out* lab.

Prerequisite: Mathematics 3, or Mathematics 1 and 2, or Mathematics 1 and Chemistry 2. (First year students taking Mathematics 1 will be placed in Chemistry 2); Mathematics 3 may be elected concurrently with Biology/Chemistry 8; however, Mathematics 3 as well as Biology/ Chemistry 8 must be completed with a passing grade before enrolling in Chemistry 9. Kull, Sloboda.

10. Honors First-Year General Chemistry

11F, 12F: 10; Laboratory M or Tu 2:00-6:00 p.m.

Chemistry 10 is a general chemistry course for students with a strong background in chemistry and mathematics who may have an interest in majoring in the sciences. The course will cover selected general chemistry topics important for higher level chemistry courses. These include thermodynamics, reaction kinetics, quantum mechanics, and bonding. Laboratory work will emphasize physico-chemical measurements and quantitative analysis.

Chemistry 10 is open *only* to first-year students and enrollment is limited. Admission is by satisfactory performance on a general chemistry proficiency test given during Orienta-tion.

Adequate mathematics preparation, equivalent to Mathematics 3, is also required. Chemistry 10 is offered in the fall term and is the prerequisite equivalent to Chemistry 5/6. Students who successfully complete Chemistry 10 will also be granted credit for Chemistry 5, if they have not already been granted such credit.

Prerequisite: Satisfactory performance on the general chemistry proficiency test and credit for Mathematics 3 or equivalent. Supplemental course fee required. *Dist: SLA*.

40. Physical Chemistry of Biochemical Processes

13W, 14W: 11; Laboratory Tu or F 2:00 - 6:00 p.m.

Topics in physical chemistry of relevance to fundamental biochemical processes. These will include the thermodynamics and statistical thermodynamics of macromolecular aqueous solutions, ligand binding and adsorption equilibria, intermolecular interactions and the hydrophobic effect, enzyme kinetics, and transport properties such as diffusion and viscosity. Laboratory exercises apply these concepts to important biophysical problems, using calorimetric, kinetic, spectroscopic and computational techniques.

Prerequisite: Chemistry 6 (or 10) and Physics 13 (or 15, or Physics 3 *and* 4) and Mathematics 8, or permission of the instructor. Students with credit for Chemistry 75 are not eligible to receive credit for Chemistry 40. Supplemental course fee required. *Dist: SLA*.

41. Biological Chemistry I

12S, 13S: 12; Laboratory M, Tu, W or Th 2:00-6:00 p.m.

This course is a one-term introduction to biochemistry presented from a chemical per-spective. This course is intended for chemistry majors and will be divided into three sec-tions, using specific examples to demonstrate and stress the role and integration of organic, inorganic and physical chemistry as applied to biochemical processes. Laboratories cover chemical methods applied to biological chemistry problems.

Prerequisite: Chemistry 52 or Chemistry 58, or permission of the instructor. Students with major credit for Biology 40 are not eligible to receive credit for Chemistry 41. Supplemental course fee required. *Dist: SLA*.

42. Biological Chemistry II

11F, 12F: 11; Laboratory M or Tu 2:00-6:00 p.m.

A one term advanced course with in-depth treatment of a number of important concepts in modern biological chemistry, including structural biology (both theoretical and experimental methods), protein folding, ligand binding, allostery, enzyme kinetics, and an introduction to molecular modeling and chemoinformatics. Laboratories will entail application of these methods/techniques.

Prerequisites: Chemistry **40 and** 41 or permission of the instructor. Supplemental course fee required. *Dist: SLA*.

51-52. Organic Chemistry

51. 11F, 12S, 12F, 13S: 11; Laboratory Tu,W or Th 2:00-8:00 p.m.

52. 12W, 12X, 13W: 11; Laboratory Tu,W or Th 2:00-8:00 p.m.

A two-term introduction to the chemistry of carbon compounds. The lectures deal with the preparation, properties, and reactions of most of the important classes of organic com-pounds. There is considerable emphasis upon reaction mechanisms and some attention is given to naturally occurring substances of biological importance.

The laboratory work will introduce the student to experimental techniques and instru-mental methods including several types of chromatography and spectroscopy, organic synthesis, and the systematic identification of organic compounds.

Prerequisite: Chemistry 6 (or 10). Chemistry 51 (or 57 with permission of instructor) is a prerequisite to 52. Supplemental course fee required. *Dist: SLA*.

57-58. Honors Organic Chemistry

57. 11F, 12F: 11; Laboratory: M 2:00-8:00 p.m.

58. 12W, 13W: 11; Laboratory: M 2:00-8:00 p.m.

A two-term introduction to the chemistry of carbon compounds intended for students planning a chemistry major or career of research in a chemically-related science, including medical science. The lectures deal with the preparation, properties, and reactions of most of the important classes of organic compounds. There is considerable emphasis on reaction mechanisms and some attention is given to naturally occurring substances of biological importance. Topics are covered in greater depth, both in lecture and in the textbook, than in the 51-52 sequence.

The laboratory work introduces the student to experimental techniques and instrumental methods including several types of chromatographic and spectroscopy techniques, organic synthesis, and identification of organic compounds.. Enrollment in Chemistry 57-58 is limited.

Prerequisite: Permission of instructor *and* either a grade of at least B+ in Chemistry 6 (or B in Chemistry 10) or a passing score on the Chemistry 6 credit test is required for Chemistry 57. Chemistry 57 (or 51 with permission of instructor) is a prerequisite to 58. Supplemental course fee required. *Dist: SLA*.

63. Environmental Chemistry

12X: 9L; Laboratory M, Tu, W, Th or F 2:00-6:00

A study of the chemistry of current environmental problems and potential solutions. The course will deal with such topics as atmospheric chemistry, chemicals and cancer, and the chemistry of resource management. A few laboratory experiments emphasizing modern methods of

instrumental analysis for substances in the environment will be included in the course.

Prerequisite: Chemistry 51 or 57, or permission of the instructor. Supplemental course fee required. *Dist: TLA*.

64. Basic Inorganic Chemistry

12W, 13W: 9L; Laboratory Th or F 2:00-6:00

A study of bonding, structure, physical and chemical properties, and chemical reactions of inorganic compounds. Examples will be drawn from main group and transition metal compounds.

The laboratory will involve preparations of inorganic compounds which illustrate appropriate experimental techniques for syntheses and manipulations, and instrumental methods for characterization of inorganic compounds.

Prerequisite: Chemistry 51 or 57, or permission of the instructor. Supplemental course fee required. *Dist: SLA*.

67. Physical Biochemistry I

12W, 13W: 11; Laboratory W 2:00-6:00

Chemistry 67 covers the structural and chemical properties of proteins and nucleic acids, including ligand binding, enzymatic catalysis, the structural basis and functional significance of protein-nucleic acid recognition, and protein folding. The course also covers the application of physical and spectroscopic techniques, including X-ray crystallography, nuclear magnetic resonance, microscopy, fluorescence and circular dichroism, to the study of biological macromolecules. The laboratory introduces these experimental methods in the study of proteins.

Prerequisite: Chemistry 41, **Chemistry 64**, Chemistry 76 **or 42**, and Chemistry 52 or 58, or permission of the instructor. Supplemental course fee required. *Dist: SLA*.

75. Physical Chemistry I

12W, 13W: 11; Laboratory M or Th 2:00-6:00

An examination of the laws of classical thermodynamics, followed by applications to the properties of gases, liquids, and solids, as well as to solutions, phase, and chemical equilibria. Chemical reaction thermodynamics and the kinetic theory of gases at equilibrium. An introduction to statistical thermodynamics, phenomenological transport and electrochemical reactions are discussed. Laboratories cover physical chemistry techniques drawn from these areas.

Prerequisites: Chemistry 6 (or 10) and Physics 13 (or 15, or Physics 3 *and* 4) and Mathematics 8, or permission of the instructor. Supplemental course fee required. *Dist: SL*A.

76. Physical Chemistry II

12S, 13S: 11; Laboratory M or Tu 2:00-6:00

Topics in chemical reaction kinetics and the application of quantum mechanics to chemical bonding and spectroscopy. The examination of the fundamental ideas of quantum mechanics and their application to simple model systems such as the linear harmonic oscillator and a confined particle, and to atomic and molecular structure. Application of quantum theory to electronic, vibrational, rotational, and magnetic resonance spectroscopies. Laboratories cover physical chemistry techniques drawn from these areas.

Prerequisites: Chemistry 75 **or Chemistry 40 *with* permission of the instructor**, and Chemistry 64. Supplemental course fee required. *Dist: SLA*.

87. Undergraduate Investigation in Chemistry

All terms: Arrange

An original and individual investigation with associated literature study in one of the fields of chemistry under the supervision of a member of the staff. *Students electing the course will carry out preliminary reading during the preceding term and normally partic-ipate in a weekly colloquium*. Open to qualified majors and minors, normally seniors, with permission of the Chair. The course may be elected more than once, *but may be counted only once in satisfying the minimum major requirements*. It may be elected for the last term in residence only if elected previously, or if the student has been doing research outside of this course.

Students electing the course write a report and take an oral examination at the end of the term in which they last elect the course.

Prerequisite: sufficient training in the area of chemistry to be investigated, and permis-sion of the Chair. Chair and staff of the Department.

90. Advanced Inorganic Chemistry: Organometallic Chemistry (*Identical to Chemistry 130*)

13S: 10 Offered in alternate years

A study of the structure, bonding, and chemical properties of organometallic compounds of the main group and transition elements. Applications to organic synthesis and homogeneous catalysis will be discussed, and organometallic compounds of the lanthanide and actinide elements may also be discussed.

Prerequisite: Chemistry 64, or permission of the instructor. *Dist: SCI*.

91. Advanced Inorganic Chemistry: Catalysis (*Identical to Chemistry 131*)

11F: 10 Offered in alternate years

The role of metals in homogeneous and heterogeneous catalysis, with an emphasis on mechanisms of catalytic reactions. Applications to industrial processes, organic synthesis, and asymmetric synthesis will be discussed.

Prerequisite: Chemistry 64, and either Chemistry 52 or Chemistry 58, or permission of the instructor. *Dist: SCI.*

92. Inorganic Biochemistry (*Identical to Chemistry 132 and Biochemistry 132*)

12S: 10 Offered in alternate years

The role of metal ions in biological systems. Topics include metal ion transport, storage, and interaction with proteins and nucleic acids; metalloproteins involved in oxygen trans-port and electron transfer; metalloenzymes involved in activation of oxygen and other substrates; and medicinal, toxicity, and carcinogenicity aspects of metals; as well as inorganic model chemistry of bioinorganic systems. Several physical methods are introduced, and their application to current research on the above topics is considered.

Prerequisite: Chemistry 64, and Chemistry 41 or Biology 40, or permission of the instructor. *Dist: SCI.*

93. Physical Organic Chemistry (*Identical to Chemistry 151*)

11F: 9L Offered in alternate years

Modern theories of organic reaction mechanisms, particularly the use of physical-chemical principles to predict the effect of changing reaction variables, especially reactant structures, on reactivity. The structure, stability, and reactivity of carbanions and carbocations, as well as SN1 and SN2 reactions, are discussed.

Prerequisite: Chemistry 52 or 58, or permission of the instructor. *Dist: SCI.*

96. Special Topics in Physical Chemistry *(Identical to Chemistry 101)*

11F, 12F, 13W: Arrange

An in-depth exploration of a specific topic in physical chemistry. This course provides an introduction into the areas of current research in the field. The course is offered every Fall and Winter term, but the content changes according to the chosen topic.

96.1 Quantum Chemistry (Formerly Chemistry 102)

96.2 Statistical Thermodynamics (Formerly Chemistry 105)

96.3 Molecular Spectroscopy (Formerly Chemistry 106)

96.4 Chemistry of Macromolecules (Formerly Chemistry 108)

96.7 Introduction to Materials Chemistry

96.8 Chemical Kinetics (Formerly Chemistry 107)

96.1 Quantum Chemistry *(Identical to Chemistry 101.1)*

An introduction to the quantum mechanics of molecular systems. Approximate methods for calculating the electronic structure of molecules are discussed. Particular emphasis is placed on

molecular orbital methods at the empirical, semi-empirical, and ab-initio levels. Evaluation of such methods for studies of molecular geometry, conformational problems, thermochemical data, and spectroscopic parameters is presented. Other topics considered include the electronic structure of hydrogen bonded systems and of excited states. Methods which include the effects of electron correlation are briefly outlined.

Prerequisite: Chemistry 76 or equivalent, or permission of the instructor. *Dist: SCI*. Ditchfield.

96.2 Statistical Thermodynamics *(Identical to Chemistry 101.2)*

Elements of equilibrium statistical thermodynamics for classical and quantum mechanical systems, with applications to ideal gases, crystalline solids, imperfect gases and liquids.

Prerequisite: Chemistry 76 or equivalent or permission of instructor. *Dist: SCI*. Cantor.

96.3 Molecular Spectroscopy *(Identical to Chemistry 101.3)*

A study of optical spectroscopy including selected topics from amongst point group theory, vibrational spectra of polyatomic molecules, electronic and vibronic spectra of molecules and rotational spectra. May be offered on tutorial basis.

Prerequisite: Chemistry 76 or equivalent, or permission of the instructor. *Dist: SCI*. Winn.

96.4 Chemistry of Macromolecules: Physical Properties and Characterization *(Identical to Chemistry 101.4)*

11F: 12

Light scattering and other characterization techniques; thermodynamic and transport properties of macromolecular solutions. Structure-property correlations in amorphous and crystalline polymers.

Prerequisite: Chemistry 75 or permission of the instructor. *Dist: SCI*. Lipson.

96.7 Introduction to Materials Chemistry *(Identical to Chemistry 101.7)*

This course begins with a review of fundamental concepts in material science, provides an introduction to some of the more advanced concepts, especially in regard to nanomaterials and, finally, focuses on the chemistry involved both in production of modern materials and their uses. The latter topics include the chemistry of thin films, self-assembled chemical systems, surface chemistry and cluster chemistry.

Prerequisite: Background in Chemistry equivalent to Chemistry 76 or Physics equivalent to Physics 24 or Engineering equivalent to Engineering 24 or permission of instructor. *Dist: SCI*. BelBruno.

96.8 Chemical Kinetics (Identical to Chemistry 101.8)

Kinetics of chemical reactions in various media: reaction rate expressions, mechanisms, elementary processes. Elementary theories of rate processes: activated complex theory, elementary collision theory, unimolecular decomposition. Such topics as diffusion control of reactions, catalysis and photochemistry will be treated as time allows.

Prerequisite: Chemistry 76 or equivalent or permission of the instructor. *Dist: SCI*. BelBruno.

101. Special Topics in Physical Chemistry *(Identical to Chemistry 96)*

11F, 12F, 13W: Arrange

An in-depth exploration of a specific topic in physical chemistry. This course provides an introduction into the areas of current research in the field. The course is offered every Fall and Winter term, but the content changes according to the chosen topic. For course descriptions, see Chemistry 96.

101.1 Quantum Chemistry (Formerly Chemistry 102)

101.2 Statistical Thermodynamics (Formerly Chemistry 105)

101.3 Molecular Spectroscopy (Formerly Chemistry 106)

101.4 Chemistry of Macromolecules (Formerly Chemistry 108)

101.7 Introduction to Materials Chemistry

101.8 Chemical Kinetics (Formerly Chemistry 107)

123. Graduate Toxicology (*Identical to Pharmacology and Toxicology 123*)

12W: Arrange Offered in alternate years

This course is open to graduate, medical and advanced undergraduate students. It pro-vides an introduction to toxicology as a discipline, with a focus on the molecular basis for toxicity of chemicals in biological systems. Major topics include: principles of cell and molecular toxicology, xenobiotic metabolism, molecular targets of cellular toxicity, genetic toxicology, chemical carcinogenesis, immunotoxicology, neurotoxicology, clinical toxicology, and quantitative risk assessment.

Faculty lectures and discussion.

Prerequisite: Undergraduate or graduate biochemistry, or permission of instructor.

124. Analytical Chemistry and Inorganic Instrumental Analysis *(Identical to Earth Sciences 124)*

13S: Arrange

This course is directed towards graduate students planning to use inorganic chemical analysis in their thesis work. The lectures and seminars focus on the theory and application of modern instrumental analysis and analytical chemistry. The theoretical background for a number of inorganic instrumental analytical methods are given and examples of their application to problems of interest to analytical chemists working in the fields of earth science, chemistry,

biology and environmental science are presented. The lectures cover ion chromatography, electrochemistry, atomic absorption, inductively coupled plasma optical emission and inductively coupled plasma mass spectrometry. The theory and concepts of analytical chemistry are provided along with statistical tools, uncertainty calculations and data treatment methods useful in analytical chemistry. Taylor.

Prerequisites: Chemistry 5 and Chemistry 6 or equivalents or permission of the instructor.

130. Advanced Inorganic Chemistry: Organometallic Chemistry (*Identical to Chemistry 90*)

13S: 10 Offered in alternate years

A study of the structure, bonding, and chemical properties of organometallic compounds of the main group and transition elements. Applications to organic synthesis and homogeneous catalysis will be discussed, and organometallic compounds of the lanthanide and actinide elements may also be discussed.

Prerequisite: Chemistry 64, or permission of the instructor.

131. Advanced Inorganic Chemistry: Catalysis (*Identical to, and described under, Chemistry 91*)

11F: 10 Offered in alternate years

Prerequisite: Chemistry 64, and either Chemistry 52 or Chemistry 58, or permission of the instructor.

132. Inorganic Biochemistry (*Identical to, and described under, Chemistry 92; also Biochemistry 132*)

12S: 10 Offered in alternate years

Prerequisite: Chemistry 64, and Chemistry 41 or Biology 40, or permission of the instructor.

137. Methods of Materials Characterization *(Identical to Physics 128 and described under Engineering Sciences 137)*

12S: 2A

Prerequisite: Engineering Sciences 24, or permission of the instructor. I. Baker.

140. Chemistry Research Colloquia

All but summer terms: W 4:00-5:00 p.m., Th 10:30-noon

Colloquia presented to the Department of Chemistry by scientists and educators in the chemistry profession on Thursdays, and by graduate students and others conducting research in chemistry and allied fields on Wednesdays as needed. The course is required of all graduate students in chemistry in each term except summer. The course is not open for credit to undergraduates. The

staff.

151. Physical Organic Chemistry (*Identical to, and described under, Chemistry 93*)

11F: 9L Offered in alternate years

Prerequisite: Chemistry 52 or 58, or permission of the instructor.

152. Advanced Organic Synthesis and Mechanisms

13W: Arrange

Consideration of organic chemical reactions at an advanced level. Current knowledge concerning synthetic methods, reaction mechanisms, reactive intermediates, conformational analysis, and biosynthesis is discussed in the context of modern organic chemistry.

Prerequisite: Chemistry 151, or permission of the instructor.

153. Chemistry of Natural Products

13S: Arrange

A survey of the application of modern synthetic methods to the total synthesis of natural products. Coverage will include retrosynthetic analysis and synthetic planning and an over-view of the preparation of a wide variety of important natural products. Emphasis will be placed on student problem-solving in the context of the synthesis of complex molecules.

Prerequisite: Chemistry 152, or permission of the instructor.

157. Topics in Advanced Organic Chemistry

12W: Arrange

Treatment at an advanced level of one or more areas of organic chemistry. The subject matter may vary from offering to offering; accordingly, the course may be taken for credit more than once.

Offered on a tutorial basis to qualified students.

159. Chemistry of Heterocyclic Compounds

12S: Arrange

An introduction to the chemical, physical, and spectroscopic properties of heterocyclic compounds. Coverage will include reactions, synthesis, stereochemistry, and unusual rearrangements. Attention will also be given to natural product synthesis and to heterocycles of biological interest.

Prerequisite: Permission of the instructor.

161. Topics in Advanced Biophysical Chemistry

Treatment at an advanced level of one or more areas of biophysical chemistry. The sub-ject matter varies from offering to offering; accordingly the course may be taken for credit more than once.

161.1, *Membrane Biophysics*. The structure and function of cell membranes, with emphasis on the complex behavior of intrinsic membrane proteins and its relation to physical properties of the lipid bilayer.

Prerequisite: Chemistry 41 and Chemistry 42 or 67, or permission of the instructor. *Dist: SCI*. Cantor, Mierke.

161.2, *Biomolecular Simulations*. An advanced treatment of modern computational approaches to the folding, structure, and dynamics of proteins and nucleic acids and their complexes. Topics include folding, searching algorithms, homology modeling, energy landscape deformation, and multi-dimensional searching. *Dist: SCI*.

Prerequisite: Chemistry 41 and Chemistry 42 or 67, or permission of the instructor. Cantor and Mierke.

161.3, *Biomolecular NMR*.

12S: Arrange

The theoretical and practical aspects of the modern use of nuclear magnetic resonance in the study of biomolecules including peptides/proteins, synthetic and natural products, and nucleic acids will be developed. Mierke.

Prerequisite: Chemistry 41 and Chemistry 42 or 67, or permission of the instructor. *Dist: SCI*.

161.4, *Structure and Dynamics of Biomolecules*.The theoretical and practical aspects for the determination of the structure and dynamics of proteins, and nucleic acids will be developed. Particular emphasis will be placed on the utilization of X-ray diffraction, cryo-electron microscopy, and high-resolution NMR and the computational approaches associated with them. *Dist: SCI*.

Prerequisite: Chemistry 41 and Chemistry 42 or 67, or permission of the instructor. Mierke.

161.5, *Protein Crystallography*. Theoretical aspects for the determination of protein structures using X-ray crystallography. Topics will include a detailed description of crystal symmetry, diffraction theory, data collection and processing, and methods for solving the crystallographic phase problem. *Dist: SCI*.

Prerequisite: Chemistry 41 and Chemistry 42 or 67, or permission of the instructor. Kull.

256. Graduate Instruction in Teaching

11F, 12F: Arrange

A course in the methodology and practice of chemistry teaching at the undergraduate college level. Topics such as laboratory supervision and safety, grading issues, special needs students, lecturing and tutoring techniques, exam preparation, and the teacher/student relationship will be discussed through readings, class discussions, and student presentations. This course is a prerequisite to the supervised undergraduate teaching requirement for the Ph.D. degree in chemistry.

Required of entering graduate students. This course is not open for credit to undergraduates. Milde, Welder.

257. Supervised Undergraduate Teaching in Chemistry

All terms: Arrange

Teaching in chemistry undergraduate courses under the supervision of a faculty member. Normally students enrolled in this course teach alongside faculty in undergraduate instructional laboratories. This course is open only to graduate students; it may be elected for credit more than once.

Prerequisite: Chemistry 256 or previous teaching experience in undergraduate chemistry courses. Chair and staff of the Department.

260-264. Graduate Research Colloquium in Chemistry

All but summer terms: Arrange

This course is available to graduate students during each term of residence, except for the summer term. An essential element of scientific training is in the critical analysis and communication of experimental research in an oral format. Evaluation will be based on quality of the work, quality of critical analysis, and on presentation style, including effective use of audiovisual materials. All enrolled students will make oral presentations that describe work from the current literature or their own research. Normally these series meet weekly. This course is not open to registration by undergraduates. The staff.

Chemistry 260, Organometallic Chemistry

Chemistry 261, Materials Chemistry

Chemistry 262, Synthetic Organic Chemistry

Chemistry 263, Bioinorganic Chemistry

Chemistry 264, Biophysical Chemistry

297. Graduate Investigation in Chemistry A

All terms: Arrange

An original and individual experimental or theoretical investigation beyond the under-graduate level in one of the fields of chemistry. This course is open only to graduate stu-dents; it may be elected for credit more than once. This course carries one course credit and should be elected by students conducting research and also electing two or more other graduate or undergraduate courses. Chair and staff of the Department.

298. Graduate Investigation in Chemistry B

All terms: Arrange

An original and individual experimental or theoretical investigation beyond the under-graduate level in one of the fields of chemistry. This course is open only to graduate stu-dents; it may be elected for credit more than once. This course carries two course credits and should be elected by students electing only departmental colloquia in addition to research. Chair and staff of the Department.

299. Graduate Investigation in Chemistry C

All terms: Arrange

An original and individual experimental or theoretical investigation beyond the under-graduate level in one of the fields of chemistry. This course is open only to graduate stu-dents; it may be elected for credit more than once. This course carries three course credits and should be elected by students conducting research exclusively in any one term. Chair and staff of the Department.

ORC: Chemistry Departmental Requirements

Chair: Peter A. Jacobi

Professors J. J. BelBruno, R. S. Cantor, R. Ditchfield, D. S. Glueck, G. W. Gribble, R. P. Hughes, P. A. Jacobi, J. E. G. Lipson, D. F. Mierke, D. E. Wilcox, J. S. Winn; Associate Professor F. J. Kull; Assistant Professors I. Aprahamian, E. V. Pletneva, J. Wu; Senior Lecturers S. P. Milde, C. O. Welder; Adjunct Professors T. U. Gerngross, U. J. Gibson, D. R. Madden, R. A. Naumann, H. M. Swartz; Adjunct Assistant Professor M. R. Spaller, Adjunct Research Assistant Professor B. P. Jackson; Research Professors D. M. Lemal, T. A. Spencer; Research Assistant Professors M. Pellegrini, A. A. Pletnev

REQUIREMENTS FOR THE CHEMISTRY MAJOR

The Chemistry Department offers five major programs. All major programs require an average GPA of 2.0 in all courses counted toward the major, including prerequisites taken in Chemistry. Normally, all courses that would serve as prerequisites to, or count toward a major in Chemistry, and that are presented at the time the student submits a major card must individually have a GPA of 2.0 or higher. Three of the major programs are offered as majors in chemistry: *Plan A,* for those who wish a broad and thorough training in chemistry; *Plan B,* for those whose scientific interests are only partially based in chemistry; and a *modified major,* which is similar to Plan B, but also includes a second program involving another college department.

Plan A should be chosen by students who plan to do graduate work in chemistry or a closely allied science. Such students should normally add further courses in chemistry, physics, and mathematics to the plan's minimum requirements. Plan A is also a suitable choice for premedical students.

Plan B is less structured and is suitable for students planning to engage in chemically-related careers, such as medicine, environmental science, life science, or industrial science, or professions for which the study of chemistry may prove desirable, such as teaching, law, or business.

The fourth program offered by the Chemistry Department is a major in biophysical chemistry. This is a relatively structured major designed for students interested in biophysical chemistry and associated methodologies for studying life processes. It provides a strong background for graduate work in biophysical chemistry, structural biology, biochemistry, and biomedical science, and is suitable for premedical students. Students are encouraged to add further courses in chemistry, biochemistry, biological sciences, mathematics, and physics to the plan's minimum requirements.

The fifth 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. In addition to being suitable for premedical students, it provides the framework for further graduate study in all areas of biological chemistry and biomedicine.

Dartmouth College requires that all majors must complete a substantial, graded culminating or integrating activity in their major. Many 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.

Other chemistry majors will satisfy the requirement for a culminating or inte-grating experience by including in their major programs one of the three-course groups listed below. The course groups, each of which provides an integrated presentation of an important area of modern chemical sciences, are: *Biophysical Chemistry* Chemistry 75, 76 and 67; ***Biological Chemistry*** **Chemistry 40, 41, and 42;** *Physical Chemistry* Chemistry 75, 76 and 96; *Chemical Applications, Synthesis and Characterization* Chemistry 63, 64, and one additional course from among Chemistry 90, 91, 92, 93.

Students must indicate their preliminary plans for satisfying the requirement for the culminating or integrating experience by the time they enroll in the major and submit their major cards. They must confirm their plans at the beginning of the fall term of the senior year. Modified majors with Chemistry as the primary department must define a culminating or integrating experience as part of the coherent and unified whole of their modified major, and must file a written statement with the Department's Undergraduate Advisory Committee and with the Registrar, explaining their rationale for the courses selected for the modified major.

The computation of the average in the major will be based upon all courses that are eligible to be counted toward the major.

1. PLAN A MAJOR

Prerequisite: Chemistry 5-6, or 9-6, or 10; Mathematics 3, 8, and 13 (or equivalents); and Physics 13-14 *(strongly recommended)* or 3-4 or 15-16.

Required Courses: Chemistry 51 or 57, 52 or 58, 64, 75, 76 and 96.

Two additional courses selected from among Chemistry 41, 42, 63, 67, 87, 90, 91, 92, 93 and 96; graduate-level courses in Chemistry; Physics 19; Biology 40; Mathematics 20, 22 or 24, 23, and 46; and, with *prior written permission,* rel-evant major credit (or graduate-level) courses in other departments in the Division of the Sciences. Chemistry 41 cannot be taken in conjunction with Biology 40.

2. PLAN B MAJOR

Prerequisite: Chemistry 5-6, or 9-6, or 10; Mathematics 3 and 8 (or equivalent); and Physics 13-14 *(strongly recommended)* or 3-4 or 15-16.

Required Courses: Of the eight courses, a minimum of six must be in chemistry to include a) Chemistry 51 or 57, 75 and 76, and 64; b) two additional courses from the following group: Chemistry 41, 42, 52 or 58, 63, 67, 87, 90, 91, 92, 93, 96 and graduate-level courses in chemistry. Note that Chemistry 76 is a pre-requisite to Chemistry 96.

The remaining two courses may be additional chemistry courses from group b) above or may be chosen from the following: Physics 19; Biology 40; Mathematics 20, 22 or 24, 23 and 46; and, with *prior written permission,* relevant major credit (or graduate-level) courses in other departments in the Division of the Sciences. Chemistry 41 cannot be taken in conjunction with

Biology 40.

3. MODIFIED MAJOR

Modified Major with Chemistry as the primary department

Prerequisite: As required by courses elected.

Required Courses: Six in total, which must include Chemistry 51 or 57, 64, and 75. The other three courses must be Chemistry Department courses. Chemistry 41 cannot be taken in conjunction with Biology 40.

Four additional courses from the secondary department selected with the approval of any member of the Undergraduate Advisory Committee (and under certain circumstances by the secondary department; see the Regulations under Department Major).

Modified Major with Chemistry as the secondary department

Prerequisite: As required by courses elected.

Required Courses: Four courses, which must be chemistry offerings, suitable (beyond prerequisites to the major) for completion of the Plan A or Plan B major.

4. BIOPHYSICAL CHEMISTRY MAJOR

Prerequisite: Chemistry 5-6, or 9-6, or 10; Mathematics 3 and 8 (or equivalent); Physics 13-14 *(strongly recommended)* or 3-4 or 15-16. (Biology 12 and 13 are recommended but not required.)

Required Courses: Chemistry 41, 51 or 57, 52 or 58, 75, 76, 64, and 67.

One additional course selected from among Chemistry 42, 63, 87, 90, 91, 92, 93 or 96; graduate-level courses in chemistry; Engineering Sciences 35; Math-ematics 20, 22 or 24, 23, or 46; Physics 19; and *with prior written permission,* relevant major credit (or graduate-level) courses in other departments in the Division of the Sciences.

5. BIOLOGICAL CHEMISTRY MAJOR

Prerequisite: Chemistry 5-6, or 9-6, or 10; Biology 12, and Biology 13 or 14; Mathematics 3 and 8 (or equivalent); Physics 13-14 *(strongly recommended)* or 3-4 or 15-16.

Required Courses: Chemistry 51 or 57, 52 or 58, 64, 40 (or 76), 41, and 42

Two additional courses selected from the following two groups, with at least one from group (a): (a) Chemistry 67, 161, 92, 87, or 153; (b) Chemistry 63, 90, 91, 93, 96, graduate courses in chemistry, or *with prior written permission*, relevant major credit (or graduate-level) courses in other departments in the Division of the Sciences.

There are many different ways in which one can complete a major in Chemistry. In order to better inform your decision, the department has prepared a handout showing various paths students can take through the major; not only does this emphasize that the major is more flexible

than it might appear at first glance, but also it shows that there are several major plans that do not require taking two major courses in a term. This document is available at

http://www.dartmouth.edu/~chem/docs/chemmajorplanning.pdf.

Students considering a Chemistry Department major are strongly encouraged to take Chemistry 5-6 (or 9-6, or 10) in their first year. Students with advanced placement in English, foreign language, or chemistry are urged to consider taking Physics 13-14 during the first year. This is also advisable for those students who delay completion of the language requirement until sophomore year in Language Study Abroad. Students who plan to participate in Language Study Abroad should give early attention to the need for careful curriculum planning. In some cases it may be advisable to postpone the LSA term to the fall term of the junior year. If so, it is necessary to obtain (routine) approval from the Registrar for deferral of completion of the Language requirement.

All Chemistry Department majors have required courses, some of which must be taken in a particular order. While many sequences are possible, and the Department's Undergraduate Advisory Committee is happy to give advice on this, it is essential to complete prerequisite courses before taking certain major courses. As a general guideline, it is recommended for majors that the physics and mathematics prerequisites for **Physical Chemistry (Chemistry 75 *and* Chemistry 76, or Chemistry 40)**, as well as Chemistry 51 or 57, be completed by the end of the sophomore spring term. Specifically, majors must complete Physics 13 (or 15, or 3 *and* 4) and Mathematics 8 before they take Chemistry 75 **or Chemistry 40**. *Any changes of courses from those listed on the major card filed with the Department must be approved in writing by a departmental adviser before the course is taken for credit.*

Many Chemistry Department majors do research projects. This research is usually done during the senior (and sometimes junior) year and often for credit (see Chemistry 87), though occasionally a stipend is available to allow a student to do full-time research during a leave term. All majors are urged to investigate the numerous possible research projects offered by chemistry faculty members. A brochure describing faculty research interests and the Chemistry 87 application form are available at http://www.dartmouth.edu/~chem and from the Department staff (102 Burke). The brochure enables a student to identify research areas of particular interest. A final choice of research project is made after consultation with the faculty member(s) concerned. The completed application form is submitted to the Chair for approval.

Certification as a public school Chemistry teacher is available through partnership with the Education Department. Contact the Education Department for details about course requirements.

REQUIREMENTS FOR THE CHEMISTRY MINOR

The Chemistry Department offers a single minor program. Any student wishing to enroll in the minor program must submit a minor card signed by a member of the Chemistry Department's Undergraduate Advisory Committee no later than the *day before final examinations begin in fall term of senior year.*

Prerequisite: Chemistry 5-6, or 9-6, or 10 and Mathematics 3

Required Courses: Chemistry 51 or 57 and 64

Two additional courses selected from among Chemistry **40,** 41, 42, 52 or 58, 63, 75, 76, 87, 90, 91, 92, and 93; or graduate-level courses in chemistry. The NRO option is disallowed for any required course taken to fulfill the chemistry minor. Students should note that many of the courses listed above have prerequisites in addition to Chemistry 6 and Mathematics 3.

REQUIREMENTS FOR THE MATERIALS SCIENCE MINOR

The minor in Materials Science is sponsored by faculty in Chemistry, Physics and Engineering with an interest in interdisciplinary education and research in materials science.

CHEMISTRY DEPARTMENT HONORS PROGRAM

A student whose grades meet the minimum College requirement for honors work may apply to be admitted to the Honors Program. An honors major follows the basic pattern outlined in the requirements for the chemistry major but is very strongly urged to elect additional courses in chemistry and allied sciences.

An honors student carries out one of two individual projects. Usually an original experimental or theoretical investigation is undertaken in a well-defined area of interest under the guidance and supervision of a member of the faculty. A student with a strong interest in teaching may, however, formulate and carry out under the direction of a member of the faculty a program combining the development of instructional materials with actual experience in classroom or laboratory teaching. In either case, on completion of the work the student will write a thesis and take an oral examination.

A student electing an original experimental or theoretical investigation may conduct it by electing Chemistry 87 three times (counting as three courses toward graduation, but only once toward the minimum group of major courses) or during a leave term of full-time effort. He or she may also request consideration of any appropriate combination of Chemistry 87 and noncredit research. A project concerned with the development of educational materials and experience in teaching will be similar in extent.

Ordinarily, the Honors Program will be undertaken by seniors, but juniors who have progressed sufficiently far in satisfying the normal requirements may be per-mitted to participate. A student who wishes to participate in the Honors Program must apply for admission to the Program by submitting a form, available from the Department staff, *before* beginning work on an honors project, unless special per-mission has been obtained from the Chair. Before or at the time of application the student must arrange for the supervision of the work, normally by a member of the faculty of the Department. *The deadline for applications is the third day of the winter term of the senior year.* Additional information is available at http://www.dartmouth.edu/~chem and from the Department administrative office.

Those students who satisfactorily complete the Honors Program with a 'B+' average or better in the grade(s) assigned to their honors work at the time of examination will earn Honors recognition in the major or, in appropriate cases, High Honors. High Honors will be granted only by vote of the Department on the basis of outstanding independent work and outstanding performance in the major. An interim evaluation of honors students will be made after one term and continuation will be recommended for those students whose work demonstrates the capacity

for satisfactory (B+) work. Students who satisfactorily complete the Honors Program will have Honors in Chemistry or Biophysical Chemistry, or, when appropriate, High Honors in Chemistry or Biophysical Chemistry, entered on their permanent record.

INTEGRATED 4+1 AB/MS PROGRAM IN BIOPHYSICAL CHEMISTRY

Objective and Overview: A 4+1 program to provide Dartmouth undergraduate students 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. With integration of the courses and a substantial effort in the independent research carried out during the senior year, the MS can be obtained in one year directly after completing the AB at Dartmouth.

Participating Faculty: Robert S. Cantor, Computational biophysics of cell membranes, protein-lipid interactions, ion channel kinetics, anesthetic mechanisms; F. Jon Kull, Protein crystallography, molecular motors, cellular transport mechanisms, enzyme mechanisms; transcription factors; bacterial virulence; cholera; Dale F. Mierke, Biophysical chemistry, high resolution NMR, peptide/compound library screening, structure-based drug-design; Ekaterina Pletneva, Biophysical and bioinorganic chemistry, heme proteins, fluorescence studies of protein conformational dynamics, redox chemistry; Dean Wilcox, Thermodynamics of metal-protein interactions, metalloenzymes, nitric oxide biochemistry.

Prerequisite Courses: Students wishing to enter the program must demonstrate proficiency in each of the following areas: biochemistry, chemistry, calculus and physics. Such proficiency will normally be demonstrated by completing the following Dartmouth College courses with at least a B grade prior to entering the Master's Program: Mathematics 8 (or equivalent) Physics 13-14 (or 15-16, or by permission 3-4) Chemistry 51-52 (or equivalent) Chemistry 41 (or by permission Biology 40) Chemistry 75-76 **or 40**.

Additionally, it is anticipated that the student will begin an independent research project with one of the participating faculty no later than the summer before senior year. An interim evaluation will be made after each term and continuation within the Master's Program will be recommended for those students whose work demonstrates the capacity for satisfactory independent research.

Admission: Students must apply for admission to the program no later than May 1 of their junior year, although interested students are strongly encouraged to contact the Program Director (Mierke) earlier for advice on prerequisites, and on the scheduling of required courses for the degree. Having explored research opportunities with members of the faculty listed above, the applicant is expected to reach an agreement on a specific project with one of the faculty. The program Admissions Committee (Cantor, Kull, Mierke) will be responsible for reviewing applications and making offers of admission, to be completed by June 30.

A complete application includes: i. A current transcript. ii. Anticipated schedule of courses for senior and fifth year. iii. The name of the research advisor and a brief description of the research project, including a timeline of research effort.

Specific Requirements for the Master's in Biophysical Chemistry are as follows:

1. Course Distribution Requirements: In addition to the prerequisite courses described above, each student must pass the following courses, either prior to beginning the Master's Program or

as part of the coursework required for the program: Chemistry 42, Chemistry 67, and at least one of the offerings of Chemistry 161 (161.1, 161.2, 161.3, 161.4, 161.5).

2. Required Course Credits: During the Master's Program, each student must pass with a grade of P or better at least eight courses from the offerings in biophysical chemistry. Two terms of Graduate Research Colloquium and up to four courses in graduate-level research may count in the eight-course total. Note: Courses taken as an undergraduate can fulfill the "Course Distribution Requirements" described above, but do not count toward the eight courses required for the Master's degree.

3. Competency Requirement: The student must demonstrate competency in the fundamentals of a biophysical chemistry methodology, including X-ray crystallography, NMR spectroscopy, fluorescence spectroscopy/FRET, experimental characterization of binding processes, or biomolecular computer simulations. This requirement will be satisfied by successful defense of the topic in an oral examination and must be completed before the end of winter term.

4. Thesis Requirement: The student must complete a satisfactory thesis based on independent-original research. The thesis must be approved by three program members and successfully defended in an oral examination.