

An interdepartmental program

Courses of Study:  
Minor

## Business

### Objectives

The Business Program (BUS) introduces undergraduates to the functions and problems of business enterprise and helps them to acquire skills and perspectives essential to a business career. Administered and staffed by the Brandeis International Business School and the School of Arts and Sciences, the curriculum allows students to combine ideas and methods from liberal arts disciplines with an intensive education in business thinking and practice.

### How to Become a Minor

The Business Program is designed to be accessible to any Brandeis undergraduate and to serve students with a broad range of interests. It welcomes all students who wish to augment their liberal arts education with a brief but sophisticated overview of business issues. Economics majors may complete this program, but students in the International Business Program (IB) may not. Students who entered Brandeis before fall 2003 may elect to complete either the IB or the BUS program; for other students, this program replaces the IB. Satisfactory completion of BUS is noted on the student's permanent record and transcript.

### Committee

**Benjamin Gomes-Casseres, Chair**  
(International Business School)

**Shih-Fen Chen**  
(International Business School)

**F. Trener Dolbear**  
(Economics; International Business School)

**Richard Gaskins**  
(American Studies)

**Andrew Molinsky**  
(International Business School; Psychology)

**Paroma Sanyal**  
(Economics)

**Dessima Williams**  
(Sociology; The Heller School)

### Faculty

**Benjamin Gomes-Casseres, Chair**  
(International Business School)

**Brenda Anderson**  
(International Business School)

**Edward Bayone**  
(International Business School)

**Alfonso Canella**  
(International Business School)

**Shih-Fen Chen**  
(International Business School)

**F. Trener Dolbear**  
(Economics; International Business School)

**Richard Keith**  
(International Business School)

**Charles Reed**  
(International Business School)

### Requirements for the Minor

**A.** Two core courses in economics and in business: ECON 2a and BUS 10a (formerly ECON 37b).

**B.** One core course in accounting and statistics: BUS 4a or BUS 6a. Students who take a statistics course in another department (e.g., ECON 83a, PSYC 51a, MATH 36a, b, or another statistics course approved by the program advising head) should take BUS 6a. Students who do not take any statistics course should take BUS 4a.

**C.** One course providing an alternative perspective on business: Any cross-listed course (e.g., not BUS), except for ECON courses.

**D.** Two electives: One should be a BUS course (except BUS 92a or BUS 98a) and the other can be any BUS or cross-listed course, including ECON courses (but not including statistics courses).

**E.** No course with a final grade below C can count toward fulfilling the requirements for the minor in business.

### Special Notes Relating to Undergraduates

No more than two courses may be double-counted for another major or minor. Upon approval of the program advising head, more advanced BUS courses in the International Business School or courses taken during a Brandeis-approved study abroad may be used as substitutes for BUS electives in the program.

Students may elect to specialize in various fields, such as globalization and business, finance, entrepreneurship, business and society, and business and government. The program advising head will advise on appropriate courses for specialization. This specialization does not appear on the student's transcript.

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## Courses of Instruction

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### (1-99) Primarily for Undergraduate Students

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#### BUS 4a Introduction to Accounting and Statistics

[ ss ]

*Prerequisite: ECON 2a. A core course for the business minor. Open only to students in the business minor who are not economics majors.*

An introduction to the accounting and quantitative skills that are central to business decision making. Includes financial statement preparation and analysis, accounting ethics, and basic statistical methods. Usually offered every year.

Ms. Andersen

#### BUS 6a Financial Accounting

[ ss ]

*Prerequisite: ECON 2a. This course may not be repeated for credit by students who have taken FIN 212a (formerly IEF 204a) or ECON 12a in previous years.*

Develops basic concepts and accounts and applies them to income measurement, capital values, and costs. Through the use of cases, develops the basis for rational choice and control of business activity. Usually offered every semester.

Mr. Keith

#### BUS 10a Functions of the Capitalist Enterprise

[ ss ]

*Prerequisite: ECON 2a (may be taken concurrently) or permission of the instructor. This course may not be repeated for credit by students who have taken ECON 37b in previous years.*

Introduces the internal complexity of modern businesses and the various roles they play in society. First examines the internal workings of firms—marketing, operations, finance, and other functions. Subsequently, the relationships between businesses and their context—the economy, social issues, and government are studied. Usually offered every semester in multiple sections.

Messrs. Bayone, Chen, and Reed

#### BUS 30a Creating New Ventures

[ ss ]

*Prerequisite: ECON 2a. An elective course for the business minor. This course may not be repeated for credit by students who have taken IEF 135b or IEF 235b in previous years.*

Focuses on the issues, ideas, and approaches of successful “bootstrap” ventures, management buyouts, and early stage operations. Topics include identifying and evaluating potential opportunities, working with investors, hiring, managing cash, and creating a sales and marketing force. Usually offered every year.

Mr. Reed

#### BUS 40a Business and the Internet

[ ss ]

*Prerequisite: ECON 2a. An elective course for the business minor. This course may not be repeated for credit by students who have taken IEF 148a in previous years.*

The Internet is changing business and reshaping competition. Which rules of business economics will apply to the Net Economy and which new ones will arise? These issues are explored, but as there are yet few clear answers, students are expected to be actively involved in shaping our collective learning. Usually offered every year. Will not be offered 2005-06.

Mr. Gomes-Casseres

#### BUS 70a Business in the Global Economy

[ ss ]

*Prerequisite: ECON 2a. This course may not be repeated for credit by students who have taken ECON 33a in previous years.*

Modern firms frequently cross national borders to find new markets and resources. Their strategies are then shaped by the international economy and by the policies of national governments. Using case discussion, students explore why and how United States, Japanese, and European firms operate outside their home countries. Usually offered every year.

Staff

#### BUS 75a Issues in Business and Management

[ ss ]

*Seniors will have priority for admission. Students must complete all other required business minor courses before taking BUS 75a. This course may not be repeated for credit by students who have taken ECON 19b in previous years.*

Explores issues central to the success of American business. Representative issue: Why have some companies developed strong export markets while others focus almost exclusively on domestic sales? Special attention is given to ethical issues and the role of the corporation and its employees as citizens of their own nation and of the world of nations. Although the topics may vary from year to year, the course may NOT be repeated for credit. Usually offered every year.

Mr. Canella

#### BUS 92a Work in the Global Business Environment: Internship and Seminar

*Normally students must arrange an internship placement prior to registration and the internship is concurrent with the seminar. Students wishing to fulfill the internship component of the course in a semester when the seminar is not offered must obtain approval from the instructor prior to the internship. A structured journal documenting the internship experience is required as a basis for seminar participation. This course may not be repeated for credit by students who have taken IB 92b in previous years.*

Encourages students to pool experiences and lessons drawn from various business environments and to analyze and discuss them in the context of related readings. Usually offered every spring.

Mr. Dolbear

#### BUS 98a Independent Study

Normally available for a student who has taken a course and wishes to pursue further reading or research in that field or study a subject not listed among the department course offerings. Usually offered every year.

Staff

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## Core Courses

#### BUS 4a

Introduction to Accounting and Statistics

#### BUS 6a

Financial Accounting

#### BUS 10a

Functions of the Capitalist Enterprise

#### ECON 2a

Introduction to Economics

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## Elective Courses

#### BUS 30a

Creating New Ventures

#### BUS 40a

Business and the Internet

#### BUS 70a

Business in the Global Economy

#### BUS 75a

Issues in Business and Management

#### BUS 92a

Work in the Global Business Environment: Internship and Seminar

#### BUS 98a

Independent Study

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## Cross-Listed Courses

#### ECON 8b

The Global Economy

#### ECON 57a

Environmental Economics

#### ECON 71a

Introduction to Finance

#### ECON 74b

Law and Economics

#### ECON 76b

Labor Economics

<b>ECON 77a</b> Introduction to Regulation and Public Policy	The following courses are eligible as “alternative perspectives on business” (refer to requirement item C on previous page):	<b>JOUR 103b</b> Advertising and the Media
<b>ECON 80a</b> Microeconomic Theory	<b>AAAS 126b</b> Political Economy of the Third World	<b>LGLS 129b</b> Law, Technology, and Innovation
<b>ECON 135a</b> Industrial Organization	<b>AMST 188b</b> Justice Brandeis and Progressive Jurisprudence	<b>PHIL 13b</b> The Idea of the Market: Economic Philosophies
<b>ECON 161a</b> International Finance	<b>AMST 189a</b> Legal Foundations of American Capitalism	<b>POL 166b</b> Seminar: Issues in International Political Economy
<b>ECON 171a</b> Financial Economics	<b>ANTH 163b</b> Production, Consumption, and Exchange	<b>POL 172b</b> Introduction to International Political Economy
<b>ECON 172b</b> Money and Banking	<b>COSI 33b</b> Internet and Society	<b>PSYC 150b</b> Organizational Behavior
<b>ECON 174a</b> Corporate Finance	<b>HIST 160b</b> American Legal History II	<b>SOC 107a</b> Global Apartheid and Global Social Movements
<b>ECON 177b</b> Economic Regulation and Deregulation	<b>HIST 179a</b> Globalization: Critical Historical Perspectives	<b>SOC 117a</b> Sociology of Work
	<b>HS 104b</b> American Health Care	
	<b>HS 110a</b> Wealth and Poverty	

## Department of Chemistry

Courses of Study:  
Minor  
Major (B.A./B.S.)  
Combined B.A./M.S.  
Master of Science  
Doctor of Philosophy

### Objectives

#### Undergraduate Major

The chemistry major offers a broad training in modern chemistry, covering the major subfields—biochemistry, inorganic, organic, and physical—and at the same time allowing students to pursue their special interest(s). Chemistry is the central science and the chemistry major provides a solid preparation for professional work in chemistry and allied fields; for study at the graduate level in chemistry and in other related fields (biochemistry, environmental science, pharmacology, polymer science, etc.); for professional schools (e.g., medicine, dentistry); and for developing an understanding of the technological and scientific issues challenging our society today—useful professionally in law and business, as well as in everyday life. Chemistry majors are given the opportunity to develop extensive, practical experience through laboratory courses using macro- and microscale techniques. Chemistry majors are encouraged to participate in independent research, which is an important part of a scientific education.

#### Graduate Program in Chemistry

The Graduate Program in Chemistry, leading to the M.S. and Ph.D. degrees, includes coursework, seminar participation, research, and teaching, and is designed to lead to a broad understanding of the subject. Entering students may be admitted to either the master’s or the doctoral program. The Ph.D. is offered with specializations in inorganic, organic, and physical chemistry. All students will be required to demonstrate knowledge in advanced areas of inorganic, organic, and physical

chemistry. The doctoral program is designed to be flexible so that individual programs of study may be devised to satisfy the particular interests and needs of each student. In each case this program will be decided by joint consultation between the student, the graduate studies committee, and the thesis supervisor, when selected. The doctoral program will normally include a basic set of courses in the student’s own area of interest, to be supplemented by advanced courses in chemistry and, where appropriate, biochemistry, biology, mathematics, and physics.

#### Ph.D. in Chemistry with Specialization in Chemical Physics

The Graduate Program in Chemical Physics is an interdisciplinary specialization designed to meet the needs of students who wish to prepare themselves for the study of scientific problems using the methods and theories of modern physics and physical chemistry. This objective is attained by (1) formal coursework in chemistry, physics, and, possibly, mathematics; (2) participation in relevant graduate seminars; (3) a program of supervised research involving chemical physics; and (4) independent study. The program is designed to be flexible in providing individual programs of study to satisfy the particular interests and needs of each student. Final programs of study and research will be arrived at by the student, the student’s research supervisor, and the chemical physics committee. Only candidates for the Ph.D. degree will be accepted. A master’s degree is not offered, but students who satisfy the appropriate requirements will be eligible for the M.S. degree in chemistry.

## How to Become an Undergraduate Major

The most important qualification for becoming a chemistry major is interest in and enjoyment of chemistry. In chemistry, as in other sciences, courses build on each other; therefore, it is important to begin early. Most students (but not all) take general chemistry and calculus in their first year. The chemistry major requires PHYS 11a,b (Basic Physics I,II), which is a prerequisite for physical chemistry (CHEM 41a,b) and advanced experimental chemistry (CHEM 59a,b). Completing PHYS 11a,b by the end of the sophomore year (strongly recommended) will allow students to take CHEM 41 and 59 during their junior year. During the fall term, interested students meet with chemistry faculty and majors at a "meet the majors" gathering called to discuss the major in chemistry. Students should consult with their faculty advisors to develop a program of courses to shape their needs and interests. To apply for the honors program, a student must select a research advisor and submit a proposed plan to the department by September 15 of his or her senior year.

## How to Be Admitted to the Graduate Program

The general requirements for admission to the Graduate School, given in an earlier section of this *Bulletin*, apply to candidates for admission to the Graduate Program in Chemistry. In addition, the undergraduate curriculum of applicants should include courses in inorganic, organic, and physical chemistry.

### Faculty

#### Peter Jordan, Chair

Statistical mechanics of membranes and of membrane transport. Modeling of ion and water pores. Molecular dynamics. Modeling peptide-membrane interaction.

#### Jeffrey Agar

Development of mass spectrometry methods for the comprehensive identification of proteins and their post-translational modifications. Current projects involve the role of protein modification in memory and neurodegeneration.

#### Iu-Yam Chan

Magnetic resonance and optical spectroscopy under pressure. Dynamics of quantum tunneling reactions.

#### Li Deng

Asymmetric catalysis and asymmetric synthesis. Solid phase synthesis and combinatorial chemistry. Chiral recognition. Chemical approaches towards understanding protein functions.

#### Milos Dolnik

Pattern formation in reaction-diffusion systems. Mathematical modeling of complex chemical reactions and gene networks. Deterministic chaos.

#### Irving Epstein

Nonlinear chemical dynamics. Spatial pattern formation, oscillations and chaos in reaction-diffusion systems. Mathematical modeling of biochemical kinetics and neural systems. Networks.

#### Bruce Foxman, Undergraduate Advising Head

X-ray structure determination. Coordination polymers. Chemical, physical, and crystallographic studies of solid-state reactions. Automatic solution of crystal structures using novel computer techniques.

#### Anne Gershenson

Protein dynamics, stability, and folding. Optical spectroscopy of single molecules. Protein engineering and directed evolution.

#### Judith Herzfeld

Solid-state NMR studies of the structure and functional mechanisms of membrane proteins. Statistical thermodynamics of spontaneous order in crowded solutions of self-assembling proteins and surfactants.

#### Philip Keehn

Synthetic methods, organic synthesis of strained rings, and theoretically interesting molecules. Host-guest complexes. Plant medicinals. Applications of NMR spectroscopy to organic systems. Photooxidation.

#### Oleg Ozerov

Organometallic chemistry. Structure, bonding, and reactivity relationships. Catalytic applications of organotransition metal complexes. Ligand promoted reactivity at transition metal centers.

#### Gregory Petsko (Director, Rosenstiel Center)

Protein crystallography, especially direct observation of transient species by low-temperature and Laue methods. Signal transduction in the process of quiescence. Protein dynamics. Protein engineering. Structure/function of proteins involved in Parkinson's disease. Yeast genetics.

#### Thomas Pochapsky

Biological redox enzymes structure and mechanism. Transient interactions in solution by NMR. NMR structures of proteins.

#### Arthur Reis

Forensic Science and DNA Replication.

#### Dagmar Ringe (Rosenstiel Center)

Protein crystallography and structural enzymology. Structure and function of PLP dependent enzymes, DNA binding proteins, and enzymes that utilize bimetallic centers for catalysis. Evolution of metabolic pathways. Rational drug design.

#### Timothy Rose

Physical and environmental chemistry, materials science, electrochemistry, photochemistry; undergraduate laboratory development.

#### Barry Snider

Development of new synthetic methods. Mechanisms of synthetically important reactions. Total synthesis of natural products.

#### Thomas Tuttle

Chemistry of liquid solutions. Composition and structures of species in metal solutions in polar solvents. Application of spectroscopy, e.g., magnetic resonance, optical and spectropolarimetry, to elucidation of the composition and structure of solutions. Theory of chemical species in solution.

#### Jinquan Yu

Asymmetric activation of sp<sup>3</sup> C-H bonds and synthetic methods, biomimetic catalysis of iron containing systems and chemical probes for life processes.

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## Requirements for the Undergraduate Major

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### Degree of Bachelor of Arts

**A.** Two semesters of general chemistry lectures (CHEM 10a,b; 11a,b; or 15a,b) with laboratory (CHEM 18a,b; 19a,b).

**B.** Five semester lecture courses, at least four of them in CHEM, chosen from among CHEM 25a,b and courses in CHEM or BCHM numbered 30 or higher (including BIOL 105b and NBIO 148b). Courses must include at least one in each of the following subfields: inorganic chemistry (CHEM 121a, 122b), organic chemistry (CHEM 25a,b), physical chemistry (CHEM 41a,b).

**C.** CHEM 29a plus three laboratory courses chosen from CHEM 29b, 39b, 59a, or 59b.

**D.** MATH 10a,b and PHYS 11a,b or 15a,b, which are prerequisites for CHEM 41a,b and CHEM 59a,b. *Students are urged to complete PHYS 11 a,b by the end of their sophomore year.* Students with AP credit for MATH 10a,b are advised to take at least one additional MATH course at Brandeis, as is generally expected by professional schools. A recently-taken math course may also strengthen preparation for physical chemistry (CHEM 41 a,b). MATH 15a, 20a, or 21a are suitable for either the medical school requirements or preparation for physical chemistry.

**E.** Additional requirements for degree with departmental honors: Two semesters of CHEM 99d (Senior Research); grade point average of 3.00 or higher in all courses taken to meet the major requirements, including laboratories. Students must petition the department by September 15 of their senior year to enter the senior honors program. Students interested in taking a program of study approved by the American Chemical Society should consult their faculty advisors.

**F.** Students planning to pursue graduate study in chemistry should be sure that their program of study includes at least two semesters each of organic chemistry lectures (CHEM 25a,b) and laboratory (CHEM 29a,b), physical chemistry lectures (CHEM 41a,b) as well as BCHM 100a. Physics laboratory (PHYS 19a,b) is also advisable.

**G.** All transfer students must pass satisfactorily a minimum of three chemistry or biochemistry courses at Brandeis at a level of CHEM 25 or higher with one of the three being CHEM 39b, 59a, or 59b.

**H.** A student may graduate with a double major in biology and chemistry if the major requirements in each department are fully met.

**I.** A student may graduate with a double major in chemistry and biochemistry if the major requirements in each department are fully met.

### Degree of Bachelor of Science

**A.** Two semesters of general chemistry lectures (CHEM 10a,b; 11a,b; or 15a,b) with laboratory (18a,b; 19a,b).

**B.** Two semesters of organic chemistry lectures (CHEM 25a,b) with laboratory (29a,b).

**C.** Two semesters of physical chemistry lectures (CHEM 41a,b).

**D.** One semester of inorganic chemistry lectures (CHEM 121a or 122b).

**E.** Three, four-credit laboratory courses (CHEM 39b; 59a,b; or one arranged with a laboratory instructor).

**F.** Two additional 100-level CHEM courses. (Either CHEM<sup>#</sup>33a or a 100-level BCHM course may be substituted for one of the two 100-level CHEM courses.)

**G.** MATH 10a,b and PHYS 11a,b or 15a,b, which are prerequisites for CHEM 41a,b and CHEM 59a,b. *Students are urged to complete PHYS 11a,b by the end of their sophomore year.* Students with AP credit for MATH 10a,b are advised to take at least one additional MATH course at Brandeis, as is generally expected by professional schools. A recently-taken math course may also strengthen preparation for physical chemistry (CHEM 41 a,b). MATH 15a, 20a, or 21a are suitable for either the medical school requirements or preparation for physical chemistry.

**H.** Additional requirements for degree with departmental honors: Two semesters of CHEM 99d (Senior Research) and a grade point average of 3.00 or higher in all courses taken to meet the major requirements, including laboratories. Students must petition the department by September 15 of their senior year to enter the senior honors program. Students interested in taking a program of study approved by the American Chemical Society should consult their faculty advisors.

**I.** For students planning to pursue graduate study in chemistry, BCHM 100a and physics laboratory (PHYS 19a,b) are also advisable.

**J.** All transfer students must pass satisfactorily a minimum of three chemistry or biochemistry courses at Brandeis at a level of CHEM 25 or higher with one of the three being CHEM 39b, 59a, or 59b.

**K.** Provisions H and I of the Bachelor of Arts requirements also apply to B.S. degrees.

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## Combined B.A./M.S. Program

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Candidates for departmental honors may be admitted to a special four-year B.A./M.S. program upon recommendation of the department and the Graduate School. Application must be made by May 1 preceding the senior year. Students must complete requirements A-E as described in the requirements for degree of Bachelor of Arts. Additionally, a 130-level organic course, a 140-level physical course, and two other 100-level courses from the School of Science must be taken. The above four courses may not also be counted toward the major requirement. Grades of B- or better are required in the 100-level science courses. Candidates should read the section "Dual Bachelor's/Master's Degree Programs" under the heading "Special Academic Opportunities," earlier in this *Bulletin*. Most notable are the three-year residence requirement and the required total of 38 courses.

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## Requirements for the Undergraduate Minor

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The minor in chemistry consists of the equivalent of six full-credit (four-semester-hour) courses and three half-credit (two-semester-hour) courses:

CHEM 11a and 11b (or CHEM 10a and 10b, or 15a and 15b)  
 CHEM 18a and 18b (or 19a and 19b)  
 CHEM 25a  
 CHEM 29a

Three additional full-credit (four semester-hour) chemistry courses that meet the major requirements. BCHM 100a, 101a, 103b, or 104b may count as one of the three courses.

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## Special Notes Relating to Undergraduates

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*Either* CHEM 10a,b lecture and CHEM 18a,b laboratory, *or* CHEM 11a,b lecture and CHEM 18a,b laboratory *or* CHEM 15a,b lecture and CHEM 19a,b laboratory will satisfy the general chemistry requirements of most medical schools. The organic chemistry requirements of most medical schools will be satisfied by CHEM 25a,b lecture and CHEM 29a,b laboratory.

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## Special Notes Relating to Graduate Students

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Chemistry colloquium lectures given by faculty and invited speakers. Participation in this noncredit activity is required of all graduate students.

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## Requirements for the Degree of Master of Science

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### Program of Study

Each candidate is required to successfully complete one year of study at the graduate level in chemistry, or, with prior permission of the graduate studies committee, in related fields. The program will include laboratory work and, normally, six term courses at the graduate level. The detailed program of study will be chosen jointly by the candidate and the graduate studies committee to reflect the candidate's area of interest as well as a perspective of other areas.

### Library Training Requirement

All graduate students are required to complete a designated library training program in their first year.

### Placement and Evaluation of Progress

Each student is expected to demonstrate a satisfactory knowledge of undergraduate chemistry in placement examinations in physical, organic, and inorganic chemistry. These examinations are set twice a year, before the start of each term. The results of these examinations will determine the student's initial program of coursework and will be considered by the graduate studies committee in evaluating the student's progress.

### Residence Requirement

The minimum residence requirement for the M.S. degree is one year.

### Teaching Requirement

It is required that all graduate students participate in undergraduate teaching during the course of their studies.

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## Requirements for the Degree of Doctor of Philosophy

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### Program of Study

A balanced program of study will be prepared by the student and the graduate studies committee. In general, students will be required to take a minimum of seven graduate-level courses, of which two must be outside the student's field of research. If a student fails to pass a placement examination after two attempts, a graduate course must be taken in that area of chemistry before the end of the second year. A list of courses appropriate for this purpose is available upon request. For students entering with a master's degree or the equivalent, two to four courses may be transferred for credit. It is expected that doctoral students will choose a research advisor during the first year.

### Placement and Evaluation of Progress

Each student is expected to demonstrate a satisfactory knowledge of undergraduate chemistry in placement examinations in physical, organic, and inorganic chemistry. These examinations are set twice a year, before the start of each term. The results of these examinations will determine the student's initial program of coursework and will be considered by the graduate studies committee in evaluating the student's progress.

Readmission to the Ph.D. degree program will be based on the student's record in coursework during the first year and his or her performance on the placement examinations. Further progress will be evaluated on a yearly basis by the graduate studies committee.

## Qualifying Examinations

The graduate student must demonstrate proficiency by taking the doctoral qualifying examinations in his or her major field: organic, physical, or inorganic chemistry. In the organic chemistry program, a cumulative examination procedure is used. Each year, six one-hour examinations (on unannounced topics) are given. The qualifying examination requirement is satisfied by passing six cumulative exams. In physical chemistry and inorganic chemistry, the student is assigned a set of propositions generally during the third term of graduate work. In physical chemistry the set consists of three propositions; the student takes a written examination on one proposition and is examined orally on all three. In inorganic chemistry the student is assigned two propositions. The student takes a written examination on one proposition and is examined orally on a research proposal (supplied either by the student or faculty) and the remaining proposition. Students in all fields must maintain satisfactory progress by passing these examinations.

### Residence Requirement

The minimum residence requirement is three years.

### Seminar

Each student in residence is required to attend and participate in the seminar in their chosen major throughout the period of graduate study. Each student is expected to present two seminars during their residence.

### Teaching Requirement

It is required that all graduate students participate in undergraduate teaching during the course of their studies.

### Library Training Requirement

All graduate students are required to complete a designated library training program in their first year.

### Language and Computer Programming Requirements

Each student in the organic and inorganic Ph.D. programs must demonstrate a useful reading knowledge of scientific French, German, or Russian within the first two years of residence. Each student in the physical chemistry Ph.D. program must demonstrate a working knowledge of Fortran, Basic, or C.

### Dissertation and Defense

A dissertation is required that describes the results of an original investigation and demonstrates the competence of the candidate in independent investigation, critical ability, and effectiveness of expression. The student must successfully defend the dissertation in a final oral examination.

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## Requirements for the Degree of Doctor of Philosophy in Chemistry with Specialization in Chemical Physics

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### Program of Study

It is expected that some candidates for the Ph.D. degree in chemistry with specialization in chemical physics may require a longer period of time in course work than will students in either of the fields of physics or chemistry. In general, the program for the Ph.D. in chemistry with specialization in chemical physics will include eight term graduate courses: four in physical chemistry, one in either organic or inorganic chemistry, and three in physics. No specific coursework in mathematics is required, but students are expected to be familiar with the techniques necessary for the proper pursuit of their research.

Students may satisfy their program's course requirements in part or in its entirety by passing (or giving evidence of ability to pass) the final examination in the appropriate number of such courses. Courses in areas related to chemistry and physics may also be considered by the chemical physics committee in partial fulfillment of the requirements.

**Placement and Evaluation of Progress**

Each student is expected to demonstrate a satisfactory knowledge of undergraduate chemistry, physics, and mathematics by the performance in three placement examinations: organic or inorganic chemistry and one each in physical chemistry and physics/mathematics. These examinations are set twice a year, before the start of each semester. The results of these examinations will determine the student's initial program of coursework and also be considered by the chemical physics committee in evaluating the student's progress.

**Qualifying Examinations**

Qualifying examinations in chemical physics are generally taken during the third term of graduate work. The student is assigned a set of three propositions; the student takes a written examination on one proposition and is examined orally on the remaining two.

**Library Training Requirement**

All graduate students are required to complete a designated library training program in their first year.

**Language and Computer Programming Requirements**

There is no foreign language requirement for the Ph.D. degree in chemical physics. Each student must demonstrate a working knowledge of Fortran, Basic, or C.

**Seminar**

Each student in residence is required to attend and to participate in the Chemical Physics Seminar. Participation in other seminars in physics and chemistry is also recommended.

**Teaching Requirement**

It is required that all graduate students participate in undergraduate teaching during the course of their studies.

**Residence Requirement**

The minimum residence requirement for the Ph.D. degree is three years.

**Dissertation and Defense**

A dissertation is required that describes the results of an original investigation and demonstrates the competence of the candidate in independent investigation, critical ability, and effectiveness of expression. The student must successfully defend the dissertation in a final oral examination.

**Courses of Instruction****(1-99) Primarily for Undergraduate Students****CHSC 3b Solving Environmental Challenges: The Role of Chemistry**

[ sn ]

*Does not meet the requirements for the major in chemistry.*

Provides a basic understanding of the chemistry of natural environmental cycles, and how these cycles are adversely affected by society. Student teams develop case studies on "hot topics" such as mercury, brominated flame retardants, MBTE, perchlorate, dioxin, and others. Usually offered every second year.

Mr. Peavey

**CHSC 5a The Magnitude of Things and How on Earth They Matter**

[ sn qr ]

*Does NOT meet requirements for the major in chemistry.*

Four statements concerning the age, condition, and destiny of Earth as affected by humans are used to implement examinations of relevant issues. These examinations require knowledge in several scientific disciplines that will be provided as the substance of the course. Usually offered every third year.

Mr. Tuttle

**CHSC 6a Forensic Science: Col. Mustard, Candlestick, Billiard Room**

[ sn qr ]

*Prerequisites: High school chemistry and biology. Does NOT meet requirements for the major in chemistry.*

Examines the use of chemical analytical instrumentation, pathology, toxicology, DNA analysis, and other forensic tools. Actual and literary cases are discussed. Error analysis, reliability, and predictability of results are considered. Usually offered every year.

Mr. Reis

**CHSC 8b Chemistry and Art**

[ sn qr ]

*Does NOT meet requirements for the major in chemistry. Lab fee: \$25.*

Topics include a scientific description of the materials and methods used in making works of art; light and color; pigments and dyes; restoration and conservation; scientific examination of artworks: the identification of fakes; and scientific probes of influence and style. Usually offered every second year.

Mr. Henchman

**CHEM 11a General Chemistry**

[ sn qr ]

*This course may not be taken for credit by students who have passed CHEM 10a or 15a in previous years.*

A basic course in chemical principles, with examples drawn from the chemistry of living systems as well as from environmental chemistry and materials science. Topics covered include stoichiometry, acid-base chemistry, chemical equilibrium, atomic structure and periodicity, molecular structure and bonding, and states of matter. Three class hours and one 90-minute recitation per week. In addition, daily tutoring sessions will be available for students seeking extra help. The corresponding lab is CHEM 18a. Usually offered every year.

Mr. Epstein

**CHEM 11b General Chemistry**

[ sn qr ]

*Prerequisite: A satisfactory grade (C- or better) in CHEM 11a or the equivalent. This course may not be taken for credit by students who have passed CHEM 10b or 15b in previous years.*

A basic course in chemical principles, with examples drawn from the chemistry of living systems as well as from environmental chemistry and materials science. Topics covered include kinetics, properties of solutions, thermodynamics, electrochemistry, coordination compounds, nuclear chemistry, and descriptive chemistry. Three class hours and one 90-minute recitation per week. In addition, daily tutoring sessions will be available for students seeking extra help. The corresponding lab is CHEM 18b. Usually offered every year.

Mr. Petsko

**CHEM 15a Honors General Chemistry: Principles of Material Evolution**

[ sn qr ]

*This course may not be taken for credit by students who have passed CHEM 10a or 11a in previous years.*

An advanced version of general chemistry for students with good preparation. Introduces the chemical principles governing the evolution of our material world through the condensation, coexistence, and aqueous stages. Three class hours and one recitation per week. The corresponding laboratory is CHEM 19a. Usually offered every year.  
Ms. Herzfeld

**CHEM 15b Honors General Chemistry: Principles of Material Evolution**

[ sn qr ]

*Prerequisite: a satisfactory grade (C- or better) in CHEM 15a or the equivalent. This course may not be taken for credit by students who have passed CHEM 10b or 11b in previous years.*

A continuation of CHEM 15a. Introduces the chemical principles governing the evolution of our material world through the photonic, biotic, and anthropic stages. Three class hours and one recitation per week. The corresponding laboratory is CHEM 19b. Usually offered every year.  
Ms. Herzfeld

**CHEM 18a General Chemistry Laboratory I**

*Corequisite: CHEM 11a. Dropping CHEM 11a necessitates written permission from the lab instructor to continue with this course. May yield half-course credit toward rate of work and graduation. Two semester hour credits. Laboratory fee: \$45 per semester. This course may not be taken for credit by students who have passed CHEM 19a in previous years.*

Introduction to methods for characterizing pure substances and methods of qualitative and quantitative analyses. Included in the analytical methods are gas chromatography-mass spectroscopy and infrared measurements. A synthesis project that includes analyzing the product by titration. Analysis of the metal content of substances by visible absorbance and atomic absorption. One laboratory lecture per week. One afternoon of laboratory per week. Usually offered every year.  
Mr. Dolnik

**CHEM 18b General Chemistry Laboratory II**

*Prerequisites: A satisfactory grade (C- or better) in CHEM 18a and CHEM 11a. Corequisite: CHEM 11b. Dropping CHEM 11b necessitates written permission from the lab instructor to continue with this course. May yield half-course credit toward rate of work and graduation. Two semester hour credits. Laboratory fee: \$45 per semester. This course may not be taken for credit by students who have passed CHEM 19b in previous years.*

The second semester of the general chemistry laboratory program. Continued use of probes interfaced with computers to monitor pH and electrical conductivity changes in titrating amino acids, to monitor pressure changes as part of a kinetics study, and to monitor voltage changes of electrochemical cells with temperature so as to establish thermodynamic parameters for redox reactions. Also microscale syntheses of coordination compounds is included followed by characterization of the compounds. Usually offered every year.  
Mr. Dolnik

**CHEM 19a Honors General Chemistry Laboratory I**

*Corequisite: CHEM 15a. Dropping CHEM 15a necessitates written permission from the lab instructor to continue with this course. May yield half-course credit toward rate of work and graduation. Two semester hour credits. Laboratory fee: \$45 per semester. This course may not be taken for credit by students who have taken CHEM 18a in previous years.*

An advanced version of CHEM 18a. One afternoon of laboratory per week. One laboratory lecture per week. Usually offered every year.  
Mr. Dolnik

**CHEM 19b Honors General Chemistry Laboratory II**

*Prerequisite: A satisfactory grade (C- or better) in CHEM 19a. Corequisite: CHEM 15b. Dropping CHEM 15b necessitates written permission from the lab instructor to continue with this course. May yield half-course credit toward rate of work and graduation. Two semester hour credits. Laboratory fee: \$45 per semester. This course may not be taken for credit by students who have taken CHEM 18b in previous years.*

Continuation of CHEM 19a. An advanced version of CHEM 18b. Usually offered every year.

Mr. Dolnik

**CHEM 25a Organic Chemistry, Lectures**

[ sn ]

*Prerequisite: A satisfactory grade (C- or better) in CHEM 10b, 11b, 15b, or the equivalent.*

Structure, reactions, preparations, and uses of the compounds of carbon. Three class hours and one 90-minute recitation per week. Usually offered every year.

Mr. Snider

**CHEM 25b Organic Chemistry, Lectures**

[ sn ]

*Prerequisite: A satisfactory grade (C- or better) in CHEM 25a or its equivalent.*

A continuation of CHEM 25a. Three class hours and one, 90-minute recitation per week. Usually offered every year.

Mr. Pochapsky

**CHEM 29a Organic Chemistry Laboratory I**

*Prerequisite: A satisfactory grade (C- or better) in CHEM 18b or 19b or the equivalent. Corequisite: CHEM 25a.*

*Dropping CHEM 25a necessitates written permission from lab instructor to continue with this course. May yield half-course credit toward rate of work and graduation. Two semester hour credits. Laboratory fee: \$45.*

Gives experience in the important techniques of organic chemical laboratory practice of isolation and purification of organic compounds by crystallization, distillation, and chromatography, and their characterization using analytical and instrumental methods. One afternoon of laboratory per week. One 90-minute laboratory lecture per week. Usually offered every year.

Mr. Keehn

**CHEM 29b Organic Chemistry Laboratory II**

*Prerequisite: A satisfactory grade (C- or better) in CHEM 29a or the equivalent. Corequisite: CHEM 25b. Dropping CHEM 25b necessitates written permission from lab instructor to continue with this course.*

*May yield half-course credit toward rate of work and graduation. Two semester hour credits. Laboratory fee: \$45.*

A continuation of CHEM 29a with an emphasis on the synthesis of typical organic compounds. One afternoon of laboratory per week. One 90-minute laboratory lecture per week. Usually offered every year.

Mr. Deng

**CHEM 33a Environmental Chemistry**

[ sn ]

*Prerequisite: A satisfactory grade (C- or better) in CHEM 10b, 11b, or 15b, or the equivalent.*

The course surveys the important chemical principles and reactions that determine the balance of the molecular species that exists in the environment and how human activity affects this balance. Topics include the critical role of energy resources and production on energy sustainability, climate change, and pollution and the chemistry controlling the composition, acidity, and nutrients in the hydrosphere and lithosphere. Factors leading to changes in the natural equilibrium such as acid rain, excessive fertilization, and release of toxic metals and pesticides are presented. The class evaluates current issues of environmental concern such as ozone depletion, global warming, radioactivity, green chemistry, gasoline additives, and chemical pollutants to develop a balanced view between the rewards achieved and the risks posed to the environment and man by current technology. The goal is to provide the background and tools necessary for assessing the chemistry of the environment for use in seeking optimal solutions to complex environmental problems. Usually offered every third year.

Mr. Rose



**CHEM 39b Intermediate Chemistry****Laboratory**

[ sn ]

*Prerequisites: Satisfactory grades (C- or better) in CHEM 121a or 122b, or permission of the instructor. Four semester-hour credits. Laboratory fee: \$45 per semester.*

In this lab the emphasis is on the synthetic inorganic chemistry. Compounds are synthesized and characterized by a wide range of instrumental methods of analysis (including GC-MS, IR, NMR.) The lectures cover the appropriate background for the synthetic experiments and the use of the instrumental methods. One afternoon of lab per week and one one-hour lecture per week. Usually offered every second year. Mr. Ozerov

**CHEM 41a Physical Chemistry, Lectures I**

[ sn ]

*Prerequisites: Satisfactory grades (C- or better) in CHEM 10b, 11b, 15b or equivalent; MATH 10a,b or equivalent; PHYS 11a,b or 15a,b. Organic chemistry is also recommended.*

Kinetic theory of gases, topics in chemical thermodynamics; introductory aspects of statistical thermodynamics. Three lecture hours per week. Usually offered every year. Mr. Chan

**CHEM 41b Physical Chemistry, Lectures II**

[ sn ]

*Prerequisites: Satisfactory grades (C- or better) in CHEM 10b, 11b, 15b, or equivalent; MATH 10a,b or equivalent; PHYS 11a,b or 15a,b. Organic chemistry is also recommended.*

Topics include quantum mechanics, spectroscopy, and chemical kinetics. Three lecture hours per week. Usually offered every year.

Ms. Gershenson

**CHEM 59a Advanced Experimental Chemistry**

[ sn ]

*Prerequisites: A satisfactory grade (C- or better) in CHEM 18b or equivalent; CHEM 41a or 41b (may be taken concurrently) or equivalent. Laboratory fee: \$45 per semester.*

CHEM 59a and b form a two-semester sequence, either half of which may be taken independently. CHEM 59a introduces the student to a number of topics of current interest in physical chemistry as well as providing experimental verification of chemical principles in thermodynamics, kinetics, macromolecules, semiconductors, nanochemistry, photochemistry and electrochemistry. The properties, reactions, and structure of compounds are understood by evaluating their physicochemical responses to changes in experimental conditions. The experiments use spectroscopy, chromatography, electrochemical and other instrumental methods employed in the modern chemical

laboratory. The program includes the methodology of quantitative measurement, statistical data analysis, and report writing. One one-hour lecture and one afternoon of laboratory per week. Usually offered every second year.

Mr. Rose

**CHEM 59b Advanced Experimental Chemistry**

[ sn ]

*Prerequisites: A satisfactory grade (C- or better) in CHEM 18b or equivalent; CHEM 41a or b (may be taken concurrently) or equivalent. Laboratory fee: \$45 per semester.*

CHEM 59a and b form a two-semester sequence, either half of which may be taken independently. CHEM 59b exposes students to a variety of physicochemical phenomena, but with a strong central theme in spectroscopy. Starting with a general discussion of interaction of radiation with matter, it develops into fluorescence spectroscopy leading to rotational relaxation of proteins in solution, Raman scattering by vibrating molecules, laser spectroscopy of molecular iodine, nanosecond kinetics of excimer formation, and circular dichroism investigation of a helix-coil transition of a polypeptide. One, one-hour lecture and one afternoon of laboratory per week. Usually offered every second year.

Mr. Chan

**CHEM 95a Directed Studies in Chemistry**

*Prerequisites: CHEM 25a and 29a, or equivalent. Does not meet the major requirements in chemistry. Laboratory fee: \$45 per semester. May not be repeated for credit. A designated library training component must be completed as soon as it is offered.*

Readings and/or independent laboratory work. Periodic conferences with advisor and a final written report. CHEM 95a and 95b may be taken individually as one-semester courses or together as a year-long sequence. Usually offered every year.

Staff

**CHEM 95b Directed Studies in Chemistry**

*Prerequisites: CHEM 25a and 29a, or equivalent. Does not meet the major requirements in chemistry. Laboratory fee: \$45 per semester. May not be repeated for credit. A designated library training component must be completed as soon as it is offered.*

Readings and/or independent laboratory work. Periodic conferences with advisor and a final written report. CHEM 95a and 95b may be taken individually as one-semester courses or together as a year-long sequence. Usually offered every year.

Staff

**CHEM 99d Senior Research**

*Prerequisites: CHEM 41a, 59a or 59b, or equivalent, which may be taken concurrently. Open only to senior honors candidates. Does not meet the major requirements in chemistry. Laboratory fee: \$45 per semester. A designated library training component must be completed as soon as it is offered. At the end of the first semester, the introduction to the research thesis with extensive bibliography is due. A year-long course focused on a research project with a member of the department. Successful completion of the course will involve the writing of a detailed report on the project. Usually offered every year.*  
Staff

**(100-199) For Both Undergraduate and Graduate Students****CHEM 110b Instrumental Analytical Chemistry**

[ sn ]

*Prerequisite: Satisfactory grade(s) in CHEM 41a and b, CHEM 59a and b, or equivalent. Laboratory fee: \$45.*

Techniques of instrumental chemical analysis. Application of instrumental methods to the separation and analysis of complex mixtures. Students rotate through ongoing research laboratories. Data treatment includes computers in the analytical chemistry laboratory. Two afternoons per week; approximately two hours of laboratory lecture and six hours of laboratory per week. Offered on request.

Staff

**CHEM 111a Computational Chemistry**

[ sn ]

*Prerequisite: Satisfactory grades in CHEM 41a and b, or equivalent.*

Selected topics in computational chemistry, including one or two of the following: small molecule modeling; biomolecular modeling; quantum mechanical modeling. Usually offered every second year.

Mr. Jordan

**CHEM 121a Inorganic Chemistry I, Lectures**

[ sn ]

*Prerequisite: A satisfactory grade in CHEM 25a and b.*

Simple bonding theory. Symmetry, structure, and bonding in inorganic compounds. Solid-state chemistry; ionic and electronic conductors. Applications of group theory and bonding theory to main group compounds and transition metal complexes. Coordination chemistry: isomerism, structure, and reactions. Usually offered every year.

Mr. Foxman

**CHEM 122b Inorganic Chemistry II,****Lectures**

[ sn ]

*Prerequisite:* A satisfactory grade in CHEM 25a and b.

Molecular orbital theory in organometallic chemistry. Acid-base concepts. Introduction to the synthesis, structure, and applications of organotransition metal compounds.

Usually offered every year.

Mr. Ozerov

**CHEM 130a Advanced Organic Chemistry: Structure**

[ sn ]

*Prerequisite:* A satisfactory grade in an undergraduate organic chemistry course.

Chemical bonding and structure, stereochemical principles and conformational analysis, organic reaction mechanisms, structures and activities of reactive intermediates, and pericyclic reactions. Usually offered every year.

Mr. Yu

**CHEM 131a Advanced Organic Chemistry: Topics in Structure and Reactivity**

[ sn ]

*Prerequisite:* A satisfactory grade in an undergraduate organic chemistry course.

Broad coverage of a variety of transformations involving additions, eliminations, substitutions, oxidations, reductions, and rearrangements. Usually offered every year.

Staff

**CHEM 132b Advanced Organic Chemistry: Spectroscopy**

[ sn ]

*Prerequisite:* A satisfactory grade in an undergraduate organic chemistry course.

Application of spectroscopy to the elucidation of structure and stereochemistry of organic compounds, with emphasis on modern NMR and MS methods. Usually offered every year.

Mr. Snider

**CHEM 134b Advanced Organic Chemistry: Synthesis**

[ sn ]

*Prerequisite:* A satisfactory grade in an undergraduate organic chemistry course.

Modern synthetic methods are covered, with an emphasis on mechanism and stereochemical control. Formation of carbon-carbon single and double bonds and carbocycles and procedures for oxidation, reduction, and functional group interchange are discussed. Selected total syntheses are examined. Usually offered every year.

Mr. Deng

**CHEM 135a Advanced Organic Chemistry: Synthesis II**

[ sn ]

*Prerequisite:* CHEM 25b or permission of the instructor.

The application of asymmetric and catalytic methods in organic synthesis is illustrated, with an emphasis on metal catalysts and stereoselectivity. Examples of trial-and-error discoveries and rational design of superior catalysts in a wide range of important reactions including hydrogenation, epoxidation, dihydroxylation, C-H activation, and C-C bond forming reactions are covered. Usually offered every second year.

Mr. Yu

**CHEM 137b The Chemistry of Organic Natural Products**

[ sn ]

*Prerequisite:* A satisfactory grade in CHEM 25a and b, or the equivalent.

Natural products chemistry is surveyed within a biosynthetic framework. Occurrence, isolation, structure elucidation, biosynthesis, and biomimetic synthesis is covered with an emphasis on modern methods of establishing biosynthesis and biomimetic syntheses. Usually offered every second year.

Mr. Snider

**CHEM 141a Chemical Thermodynamics**

[ sn ]

*Prerequisite:* Satisfactory grade in undergraduate physical chemistry. Familiarity with multivariable calculus. Statistical, classical, and irreversible thermodynamics; principles, tools, and applications. Usually offered every year.

Staff

**CHEM 141b Kinetics**

[ sn ]

*Prerequisite:* A satisfactory grade in undergraduate physical chemistry. Macroscopic kinetics: elementary reactions and rate laws. Kinetic study of reaction mechanisms: techniques for kinetic measurements; fast reactions; treatment of kinetic data. Microscopic kinetics: molecular dynamics, transition state theory. Reactions in the gas phase and in solution. Catalytic and chain reactions. Enzyme kinetics. Nonlinear dynamics: chemical oscillations and waves. Usually offered every year.

Mr. Steel

**CHEM 142a Quantum Chemistry**

[ sn ]

*Prerequisite:* Passing grades in CHEM 41a and b, or equivalent.

This class will discuss solutions of the Schroedinger equation for simple systems; operator techniques and approximation methods; atoms; diatomic molecules; polyatomic molecules; introduction to quantum chemical calculation; density matrix formalism. Usually offered every second year.

Mr. Jordan

**CHEM 147b Physical Chemistry - Mass Spectrometry**

[ sn ]

*Prerequisite:* CHEM 11b or permission of the instructor.

The processes of ionization, ion separation, and ion detection is taught at the theoretical level, and applied to understanding modern mass spectrometry. Usually offered every second year.

Mr. Agar

**CHEM 150b Special Topics in Chemistry**

[ sn qr ]

Topics vary from year to year. Usually offered every third year.

Staff

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**(200 and above) Primarily for Graduate Students**

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**CHEM 200a Advanced Chemistry Laboratory I**

Usually offered every year.

Staff

**CHEM 200b Advanced Chemistry Laboratory II**

Usually offered every year.

Staff

**CHEM 220c Inorganic Chemistry Seminar**

Required of graduate students in inorganic chemistry every semester.

Staff

**CHEM 229b Special Topics in Inorganic Chemistry: Introduction to X-Ray Structure Determination**

Topics include basic diffraction and space group theory, practical manipulations of crystals and X-ray diffraction equipment, solving crystal structures, and interpretation of structural chemistry. Course will feature self-paced exercises on PCs. Usually offered every second year.

Mr. Foxman

**CHEM 231c Organic Chemistry Seminar**

Required of graduate students in organic chemistry every semester.

Staff

**CHEM 232b Heterocyclic Chemistry**

The nature of aromatic heterocycles will be surveyed, followed by detailed discussion of their characteristic reactions and modes of synthesis. The course is organized to show a general predictive framework behind the details. Emphasis is placed on the mechanisms of heterocycle reactions. Usually offered every third year.

Staff

**CHEM 234b Chemistry of Organometallic Compounds**

The chemistry of organo-transition metal complexes, including their structures, bonding, reactivity, and use in industrial processes and organic synthesis. Usually offered every second year.

Mr. Ozerov

**CHEM 235b Advanced NMR Spectroscopy**

A detailed discussion of modern NMR methods will be presented. The course is designed so as to be accessible to nonspecialists, but still provide a strong background in the theory and practice of modern NMR techniques. Topics include the theory of pulse and multidimensional NMR experiments, chemical shift, scalar and dipolar coupling, NOE, spin-operator formalism, heteronuclear and inverse-detection methods, Hartmann-Hahn and spin-locking experiments. Experimental considerations such as pulse sequence design, phase cycling, and gradient methods will be discussed. Guest lecturers will provide insight into particular topics such as solid-state NMR and NMR instrumental design. Usually offered every third year.

Mr. Pochapsky

**CHEM 241c Physical Chemistry Seminar**

Required of graduate students in physical chemistry every semester.

Staff

**CHEM 243b Statistical Thermodynamics**

Elementary statistical mechanics of ensembles of molecules and applications to thermodynamic systems. Usually offered every third year.

Mr. Jordan

**CHEM 245a Ultrafast Spectroscopy**

Ultrafast laser-based spectroscopy techniques and their applications to chemical and biological systems are presented. Topics include the generation of femtosecond laser pulses, pump-probe spectroscopy, time and frequency domain spectroscopy, and ultrafast dynamics of chemical reactions and biomolecular motions. Usually offered every third year.

Ms. Gershenson

**CHEM 250c Chemical Physics Seminar**

Required of graduate students in chemical physics every semester.

Staff

**CHEM 298a Independent Study**

Usually offered every year.

Staff

**CHEM 401d Dissertation Research**

Independent research for the Ph.D degree. Specific sections for individual faculty members as requested.

Staff

**Chemistry Colloquium**

Lectures by faculty and invited speakers.

Required of all graduate students.

Noncredit.

**Courses of Related Interest****NBIO 136b**

Computational Neuroscience