CHEMISTRY

haverford.edu/chemistry

The program in chemistry is designed to meet the needs of students who are pursuing chemistry either for a variety of pre-professional reasons or to increase their knowledge of the natural sciences. Therefore, Haverford has a chemistry major program that provides preparation for careers in science, medicine, law, business, K-12 education, as well as a number of other professions.

The major program recognizes that chemistry as a discipline is a core science but is also intertwined with a number of other fields, including physics, biology and math/computer science. In fact, some of the most exciting areas in science today are found in the interdisciplinary fields of chemical physics, chemical biology, theoretical/ computational chemistry, environmental studies and materials science. The chemistry major allows the student flexibility in designing a program that can be directed toward such interdisciplinary areas or to one of the more traditional areas of organic, physical, or inorganic chemistry. In addition, the Chemistry Department is one of the sponsor departments of the concentrations in Scientific Computing and Biochemistry and Biophysics and contributes courses to the minor in Environmental Studies.

LEARNING GOALS

Our major goal is to provide our students with the most rigorous education in the core concepts of chemistry.

- Students will understand and apply basic research methods as used professionally in chemistry, including research design, data analysis, and interpretation.
- Students will understand the fundamental basis for the structures and reactivities of atoms, molecules and non-molecular solids and the analytical techniques used for their determination.

CURRICULUM

Introductory Courses

Students interested in majoring or minoring in chemistry, or those who wish to take chemistry in support of another science major or a preparation for careers in medicine or other health-related fields, have three possible entry points into our course sequences. The particular entry point or placement depends on the level of preparation of the individual student and is determined by the combination of results from a placement questionnaire and individual consultation. Students with no to limited previous chemistry experience enter the first-year chemistry sequence with the intensive courses CHEM 113 (Structure and Bonding), followed by CHEM 114 (Chemical Dynamics). Students with typical high school chemistry preparation enroll in non-intensive courses that cover the same material. The third entry point is for students with an excellent high school chemistry background, who take CHEM 115, which includes the CHEM 111 lecture and a more investigative, independent lab program, followed by CHEM 112. All students can continue the following year with CHEM 222, a course in organic biological chemistry and CHEM 225, which is focused on organic synthesis. Pre-medical students should continue through at least CHEM 222, and may need to take additional organic or biochemistry courses depending on the requirements of medical schools.

The Chemistry Department typically also offers each year at least one course at the 150 level that is without prerequisites and does not count toward the major. These courses are designed to give students majoring in all fields an appreciation for and understanding of important chemical concepts and theories and their applications to our contemporary world.

Research

Research is the characteristic activity of chemists, and the Chemistry Department believes that students should be involved in research as part of their chemical education. As juniors (typically) our majors take intensive integrated laboratory courses ("Superlabs"; CHEM 301, 302 and Biochemistry 390) designed to teach the laboratory, computer, experimental design and communication skills needed for independent research. All senior chemistry majors are required to write a senior thesis based on mentored research for which they get course credit. Students at any level of the curriculum can obtain laboratory research experience through paid summer internships or by enrolling in research tutorial (CHEM 26x and 36x) courses during the academic year, and most majors do both. Typically two to six students work in each faculty

member's laboratory during any given semester or summer. Chemistry majors who wish to work elsewhere for the summer have been successful at securing summer research positions in university, government, and industrial chemical laboratories. The senior research thesis also comprises communicating research work in different formats, including an oral presentation in our weekly, year long departmental seminar series, which also includes invited speakers, and a poster presentation at the end of the academic year.

This research experience nurtures talents and abilities, encourages independent problem solving and builds on concepts and principles discussed in prior formal class work. It also can help the student define choices for careers after graduation. Research allows students to discover and develop creativity and independence, which the well-structured programs of the formal courses do not always adequately address. Student and faculty research in the department is supported by grants from the National Science Foundation, the National Institutes of Health, and several other sources. Students are also encouraged to present their research work at regional and national conferences. Students and faculty from the Chemistry Department publish their research findings in top tier peer-reviewed journals; publications are listed at the Chemistry Department web site.

Also see the Chemistry Department website for a detailed writing guide for students enrolled in chemistry courses (PDF download).

MAJOR REQUIREMENTS

The core required courses are:

- four semesters of introductory and organic chemistry: CHEM 111, 113 OR 115, CHEM 112 OR 114, CHEM 222, and CHEM 225.
- two semesters of advanced integrative chemistry laboratory ("Superlab"): CHEM 301 and 302.
- one semester of physical chemistry: CHEM 304 or 305.
- one semester of senior research tutorials: CHEM 36x or 380.
- two half-semester courses in inorganic chemistry: CHEM 320 and one of 351, 353, or 354.
- Senior Seminar: CHEM 391 (a half credit course over two semesters).

Chemistry majors must also complete:

- one semester of additional advanced chemistry courses numbered 304-358.
- one semester of math (MATH 118 or above).
- two semesters of either introductory physics (PHYS 101/102 or 105/106) or biology (BIOL 200).

ACS-Certified Chemistry Major

An American Chemical Society (ACS) certified major requires additional coursework and is recommended for students interested in pursuing graduate study in science and engineering, or who wish to directly enter the job market in a chemistry- related field after graduation.

In order to receive ACS-certification, students must satisfy all of the major requirements in a way that includes a year of physics and a semester of biochemistry (this is automatic for biochemistry concentrators), and also must take one additional physical chemistry course. Specifically, ACS-certified majors must complete:

- both semesters of physical chemistry (CHEM 304 and 305); for ACS-certified majors these courses do not fulfill the additional advanced course requirement.
- two semesters of introductory physics (101/102 or 105/106).
- one semester of biochemistry, which can be BIOL 200 (second semester), two half-semester courses from CHEM351, 352, 357 and 359, or equivalent, such as Bryn Mawr Chemistry 242 or higher.

MINOR REQUIREMENTS

- Four semesters of introductory and organic chemistry: CHEM 111, 113 OR 115, CHEM 112 OR 114, CHEM 222, and CHEM 225.
- One semester of physical chemistry: CHEM 304 or 305.
- One semester of advanced chemistry chosen from courses numbered between 301 and 369.

Students must take at least three of the courses for the chemistry minor at Haverford College. The Senior Seminar (CHEM 391) is not required, but recommended.

SENIOR PROJECT

The senior project in chemistry has two major components. First, all seniors enroll in CHEM 391 Senior Seminar, a year-long seminar course. Second, all seniors enroll in at least one credit of

research, either experimental, computational or literature-based. The course numbers for research as specific to the faculty advisors, often with a CHEM 36x designation. CHEM 36x work involves the design, articulation and conduction of an independent research project. Students are expected to be in the laboratory for at least 15 hours per week performing experiments, analyzing data and designing future experiments. Additional activities include participation in research group meeting, where data, experiments and literature articles are discussed. Each student prepares a formal document at the end of their spring semester detailing their work in the Senior Project. This document is generally due on the last day of classes in the spring semester.

CHEM 391 is designed to expose students to chemistry through talks by chemists from other institutions and to provide our students with opportunities to present their own work formally. Each student prepares and delivers both an oral and poster presentation. The oral presentations occur between December and March, while the poster presentations occur in April. The audience for these presentations is all chemistry seniors, underclass students involved in research, post-doctoral fellows and the faculty in chemistry.

Senior Project Learning Goals

Identify and describe research methods used to probe specific chemical motifs.

- This learning objective involves the correct use various instrumental analyses in the full characterization of different reaction types. This learning objective most likely fits into the junior level CHEM 301/302 Lab in Chemical Structure and Reactivity (Superlab).

Design and articulate an independent research project.

- This learning objective is designed to probe a student's ability to digest the chemical literature, formulate new ideas and articulate them clearly. This objective will take the form of an independent research proposal that is based upon the primary literature and includes new ideas and directions. This would serve a few purposes. First, it would provide preparation for senior thesis experience in that they need to be able to propose future experiments in current projects. Second, it would provide another source for the evaluation of their critical thinking skills.

Critique conclusions presented in the primary literature.

- This learning objective is designed to measure a student's ability to analyze and critique the primary literature. This is performed routinely in the advanced level courses offered by the Chemistry Department.

Senior Project Assessment

The Chemistry Department's assessment of a student's capstone experience involves three major components: research efforts, oral presentation skills and the written thesis. We seek to help students develop and demonstrate the following behaviors and skills.

Chemistry Research Grades

Senior research grades encompass several different components, including your research efforts, the quality of your thesis and your participation in senior seminar. This document is designed to convey our expectations of you in your research experience and to help you interpret your grades.

Research

A 4.0 student will:

- demonstrate independent intellectual involvement in their project.
- show evidence of productivity that is commensurate with the amount of credit assigned to 36x.
- make creative contributions to the design and analysis of experiments.
- propose independent ideas to overcome research obstacles.
- proactively use the primary literature as an integral resource.
- interpret their own data and develop ideas for subsequent studies.
- maintain a clear and complete laboratory notebook.
- display critical thinking in lab meetings.
- work to maximize research progress during the year.

Thesis

A 4.0 student will:

- clearly describe the context of the project in the greater literature.
- briefly summarize the history or related studies.
- explain the novelty of the work described in the thesis.

- detail experimental methodologies to the level of detail with which one could reproduce all experiments.
- identify the strengths and limitations of each technique used.
- summarize and interpret all results.
- analyze the outcome of their experiments in the context of the greater literature, with particular emphasis on continued progress of the research project.
- clearly display experimental data through the use of tables and figures, when appropriate.
- fully and consistently cite literature precedence.

Seminar
A 4.0 student will:

- clearly construct and deliver an oral and poster presentation in which the relevance, novelty and preliminary results are communicated clearly within the given constraints.
- demonstrate the progress of their project between the oral and poster presentations.
- answer post presentation questions completely.
- be an active participant in other presentations (by both students and outside speakers) by asking questions.

Grades for each student are assigned by the student's research supervisor using the criteria described above. Student theses, presentations and experimental efforts are discussed at a meeting of the chemistry faculty at the end of each academic year.

An additional level of assessment is used for each student. The department scores each student in the following categories; oral presentations, intellectual contributions, command of the literature, experimental skills, and written work. These "scores" for each student are either "fails to meet expectations", "meets expectations", or "exceeds expectations". These data are tracked from year to year to allow the department to observe and emerging trends and challenges and to adapt our program to foster success in our students.

REQUIREMENTS FOR HONORS

All students who participate in Senior Research (CHEM 36x) for two semesters (or for one semester with an appropriate summer research experience) will be considered for departmental honors. Successful honors candidates will be expected to do superior work in major courses and to complete a research project at a level superior both in quality and quantity of effort to that expected in normal course work.

CONCENTRATIONS AND INTERDISCIPLINARY MINORS

Students who major in chemistry may choose to minor or concentrate in any of several related disciplines. For more information about these programs and their requirements, please see each program's website or catalog entry.

Environmental Studies Minor
The Environmental Studies Interdisciplinary Minor aims to cultivate in students the capacity to identify and confront key environmental issues through a blend of multiple disciplines, encompassing historical, cultural, economic, political, scientific and ethical modes of inquiry.

In the Chemistry Department, courses that contribute to this minor are CHEM 112, 150 and 358.

Neuroscience Minor
The minor in Neuroscience is designed to allow students with any major to pursue interests in behavior and the nervous system across disciplines. Students should consult with any member of the advisory committee in order to declare the minor.

Biochemistry Concentration
Haverford's Concentration in Biochemistry and Biophysics is located at the interface between the biological, chemical, and physical sciences. For our ambitious students and faculty who seek to understand biological processes from physical and chemical points of view, this is an especially exciting place to be. We offer a range of courses of study depending on the student's particular area of interest.

Scientific Computing Concentration
The Concentration in Scientific Computing gives students an opportunity to develop a basic facility with the tools and concepts involved in applying computation to a scientific problem, and to explore the specific computational aspects of their own major disciplines.

In the Chemistry Department, courses that contribute to this concentration are CHEM 304, 305, and 362; students are also encouraged to enroll in CHEM 322 when offered at Bryn Mawr College.

AFFILIATED PROGRAMS

4+1 Engineering Program with the University of Pennsylvania

Haverford College and the University of Pennsylvania have formed a partnership that enables qualified Haverford undergraduates to gain early and expedited admission into a Master's degree offered by Penn Engineering. Study for four years at Haverford, then one year at Penn, and receive a Bachelor of Science degree from Haverford and a Master's in Engineering from Penn. Haverford is the first liberal arts college in the world to enter into such an agreement with an Ivy League engineering program.

STUDY ABROAD

Chemistry majors wishing to study abroad during the junior year should confer with the faculty advisor and typically take at least one chemistry or biochemistry course per semester at the foreign institution. The Chemistry Department has currently approved international study abroad programs at Oxford University (England), University College London (England), University of Melbourne (Australia), University of Lund (Sweden) and University of Aberdeen (Scotland). Chemistry majors have also recently studied at University of Stockholm (Sweden), Queen's University (Northern Ireland), National University of Ireland (Ireland), University of the West Indies (Barbados) and University of Cape Town (South Africa).

AFTER GRADUATION

About one third of Haverford's chemistry majors enter top-ranked graduate programs leading to a Ph.D., and another third enter medical school after graduation. The remaining third of Haverford's chemistry majors obtain challenging and rewarding positions as teachers, laboratory scientists, and information specialists, among other professions.

FACULTY

Karin Åkerfeldt
Professor

Frances Blase
Provost of the College and Associate Professor

Robert Broadrup
Visiting Assistant Professor

Louise Charkoudian *(on leave Fall 2017)*
Assistant Professor

Michael Kukla
Organic Reactions and Synthesis Laboratory Instructor

David Laviska
Visiting Assistant Professor

Casey Londergan *(on leave Fall 2017)*
Associate Professor

Kelly Matz
First-Year Chemistry Laboratory Instructor

Alexander Norquist *(on leave 2017-2018)*
Professor

Stephen Podowitz-Thomas
Visiting Assistant Professor

Robert Scarrow
Professor

Joshua Schrier
Chair and Associate Professor

Mark Stein
Organic Biological Chemistry Laboratory Instructor

Jessica Stuart
Visiting Assistant Professor

Helen White
Associate Professor

Yang Yang
Visiting Assistant Professor

Emeritus Faculty:

Colin MacKay
John Farnum Professor of Chemistry, Emeritus

Terry Newirth
Professor Emeritus

Claude E. Wintner
Professor Emeritus

COURSES

CHEM H111 CHEMICAL STRUCTURE AND BONDING

Robert Scarrow, Kelly Matz
Natural Science (NA)
Structure and bonding in molecules starting from nuclear and electronic structure of atoms. This course introduces the theories of chemical bonding that rationalize and predict the structures and bulk properties of molecules and materials. It also introduces modern instrumental and computational methods used to study chemical structure and bonding. Three lectures and one lab period per week required. Recitations are optional. (Offered Fall 2017)

CHEM H112 CHEMICAL DYNAMICS

Stephen Podowitz-Thomas, Kelly Matz
Natural Science (NA), Quantitative (QU)
An introduction to chemical thermodynamics, equilibrium, electrochemistry and kinetics. Microscopic properties are used to develop basic chemical concepts of energy, enthalpy, entropy, and the Gibbs Energy, and their applications to thermochemistry, equilibria, and electrochemistry. Chemical kinetics, reaction mechanisms, and applications to chemical problems are also discussed. Recitation Options: M 2-3 or Tu 9-10 or Tu 3-4. Prerequisite(s): Placement by the Chemistry Department (Offered Spring 2018)

CHEM H113 INTENSIVE: CHEMICAL STRUCTURE AND BONDING

Jessica Stuart
Natural Science (NA)
Structure and bonding in molecules starting from nuclear and electronic structure of atoms. This course introduces the theories of chemical bonding that rationalize and predict the structures and bulk properties of molecules and materials. It also introduces modern instrumental and computational methods used to study chemical structure and bonding. This is a more intensive offering of CHEM 111 designed for students with little or no experience in chemistry. (Offered Fall 2017)

CHEM H114 INTENSIVE: CHEMICAL DYNAMICS

Helen White, Kelly Matz
Natural Science (NA)
An introduction to chemical thermodynamics, equilibrium, electrochemistry and kinetics. Microscopic properties are used to develop basic chemical concepts of energy, enthalpy, entropy, and the Gibbs Energy, and their applications to thermochemistry, equilibria, and electrochemistry. Chemical kinetics, reaction mechanisms, and applications to chemical problems are also discussed. This is a more intensive offering of CHEM 112 designed for students with little or no experience in chemistry. Prerequisite(s): Placement by the Chemistry Department (Typically offered every spring)

CHEM H115 CHEMICAL STRUCTURE AND BONDING WITH INQUIRY LAB

Robert Scarrow, Jessica Stuart
Natural Science (NA)
Structure and bonding in molecules starting from nuclear and electronic structure of atoms. This course introduces the theories of chemical bonding that rationalize and predict the structures and bulk properties of molecules and materials. In the lab, students will become acquainted with modern methods of chemical structure analysis as they discover the identity of unknown compounds via self-proposed experiments. Three lectures, one lab period, and one laboratory planning meeting each week. Recitations are optional. (Offered Fall 2017)

CHEM H151 CASE STUDIES IN CHEMISTRY: THE SCIENCE OF COLOR AND LIGHT

Stephen Podowitz-Thomas
Natural Science (NA)
This course is intended for non-science majors. Have you ever wondered what makes the sky appear blue, an apple appear red, and the sun appear a yellowish white at midday? In this course, we will discuss the underlying physical processes that are involved in the production of light and the ways in which its interaction with matter leads to the colors we see in the objects that make up the world around us. The chemistry of the pigments in paints and the phosphors in LED and fluorescent light fixtures will be covered, along with current challenges and opportunities that advances in the design and chemistry of energy-efficient lighting technology have presented for the way in which we may control the colors of the objects that they light. We will also discuss the ways in which color scientists quantify color and the challenges that are

involved in building a standardized system that is based on not only a physical, but also a physiological and potentially social phenomenon, whose perception may vary widely across and within populations. (Offered occasionally)

CHEM H222 ORGANIC BIOLOGICAL CHEMISTRY
Karin Åkerfeldt, Mark Stein
Natural Science (NA)
Survey of organic chemistry reactions in an aqueous environment, highlighting transformations important for understanding the properties and reactivity of biomolecules in the cell, with emphasis on functional groups, acids and bases, chirality, energetics, reaction mechanisms, enzyme inhibitors and drug design. One lab per week required. One recitation per week required. (Offered Fall 2017)

CHEM H225 ORGANIC REACTIONS AND SYNTHESIS
Robert Broadrup, Michael Kukla
Natural Science (NA)
This course will explore organic reactions in mechanistic detail, and highlight their use in the syntheses of complex organic molecules. It will concentrate on functional group transformations and then delve into organometallic and enantioselective reactions for use in complex syntheses. Recitation Options: Th 9-10 or F 1-2. Prerequisite(s): CHEM 111 or 115, & CHEM 112 & 222, or instructor consent. (Typically offered every spring)

CHEM H261 RESEARCH TUTORIAL IN PHYSICAL CHEMISTRY
Casey Londergan
Natural Science (NA)
One-half credit course for the year designed for students interested in the chemistry research experience in physical chemistry, condensed phase chemical physics, and biophysical chemistry, with emphasis on spectroscopic studies of peptides and proteins. (Not open to seniors.) Prerequisite(s): Instructor consent. (Offered Fall 2017)

CHEM H262 RESEARCH TUTORIAL IN THEORETICAL CHEMISTRY
Joshua Schrier
Natural Science (NA)
One-half credit course for the year designed for students interested in the chemistry research experience in theoretical physical chemistry, with emphasis on methods for prediction of optical, electronic, and mechanical properties of semiconductor nanostructures. (Not open to seniors.) Prerequisite(s): Instructor consent. (Offered Fall 2017)

CHEM H263 RESEARCH TUTORIAL IN ORGANIC CHEMISTRY
Frances Blase
Natural Science (NA)
One-half credit course for the year designed for students interested in the chemistry research experience in synthetic organic chemistry and physical-organic chemistry. Topics include total synthesis of biologically significant molecules, new methods of enantioselective synthesis, and the study of organic reaction mechanisms. (Not open to seniors.) Prerequisite(s): Instructor consent. (Offered Fall 2017)

CHEM H264 RESEARCH TUTORIAL IN BIOORGANIC CHEMISTRY
Karin Åkerfeldt
Natural Science (NA)
One-half credit course for the year designed for students interested in the chemistry research experience in protein structure-function relationship studies and the design and synthesis of a broad range of peptides, proteins and biologically inspired novel materials. (Not open to seniors.) Prerequisite(s): Instructor consent. (Typically offered every semester)

CHEM H265 RESEARCH TUTORIAL IN BIOINORGANIC CHEMISTRY
Robert Scarrow
Natural Science (NA)
One-half credit course for the year designed for students interested in the chemistry research experience in spectroscopic and kinetic studies of metalloproteins and inorganic coordination compounds. (Not open to seniors.) Prerequisite(s): Instructor consent. (Offered Fall 2017)

CHEM H267 RESEARCH TUTORIAL IN BIOLOGICAL CHEMISTRY
Louise Charkoudian
Natural Science (NA)
One-half credit course for the year designed for students interested in the chemistry research experience in natural product biosynthesis. (Not open to seniors.) Prerequisite(s): Instructor consent. (Offered Fall 2017)

CHEM H268 RESEARCH TUTORIAL IN ENVIRONMENTAL CHEMISTRY
Helen White
Natural Science (NA)
One-half credit course for the year designed for students interested in the chemistry research experience in the field of biogeochemistry, a multidisciplinary approach focused at understanding the chemical composition and processes of Earth's biosphere. (Not open to seniors.) Prerequisite(s): Instructor consent. (Offered Fall 2017)

CHEM H269 RESEARCH TUTORIAL IN MATERIALS SCIENCE
Alexander Norquist
Natural Science (NA)
One-half credit course for the year designed for students interested in the chemistry research experience in the field of biogeochemistry, a multidisciplinary approach focused at understanding the chemical composition and processes of Earth's biosphere. (Not open to seniors.) Prerequisite(s): Instructor consent. (Offered Fall 2017)

CHEM H300A LABORATORY IN BIOCHEMISTRY AND MOLECULAR BIOLOGY
Judith Owen
Natural Science (NA)
One lecture and two laboratory periods per week. An introduction to the application of modern experimental approaches in the study in interesting biological questions. Techniques employed are drawn from: cloning and nucleic acids (DNA and RNA) manipulation, including polymerase chain reaction (PCR) and site-directed mutagenesis; protein expression, purification and characterization, with emphasis on circular dichroism and fluorescence spectroscopy; immunofluorescence, confocal and electron microscopy; and fluorescence-activated cell sorting (FACS) analysis. Preference for a specific lab section will be given to students preregistering for that lab section; students who do not preregister will be assigned on a space available basis. Crosslisted: Biology, Chemistry; Prerequisite(s): Successful completion of BIOLH 200A and B with grades of 2.0 or higher, or instructor consent. (Offered Fall 2017)

CHEM H300B LABORATORY IN BIOCHEMISTRY AND MOLECULAR BIOLOGY
Rachel Hoang
Natural Science (NA)
One lecture and two laboratory periods per week. An introduction to the application of modern experimental approaches in the study in interesting biological questions. Techniques employed are drawn from: cloning and nucleic acids (DNA and RNA) manipulation, including polymerase chain reaction (PCR) and site-directed mutagenesis; protein expression, purification and characterization, with emphasis on circular dichroism and fluorescence spectroscopy; immunofluorescence, confocal and electron microscopy; and fluorescence-activated cell sorting (FACS) analysis. Preference for a specific lab section will be given to students preregistering for that lab section; students who do not preregister will be assigned on a space available basis. Crosslisted: Biology, Chemistry; Prerequisite(s): Successful completion of BIOLH 200A and B with grades of 2.0 or higher, or instructor consent. (Typically offered every spring)

CHEM H301 LAB IN CHEMICAL STRUCTURE AND REACTIVITY
Robert Broadrup, Stephen Podowitz-Thomas
Natural Science (NA)
Two lectures and two laboratory periods. An introduction to the methods of research in chemistry. Inorganic, organic, physical chemistry, computational chemistry, and biochemical concepts are integrated in a broad laboratory study of structure and its relationship to chemical reactivity. Physical methods are used in studies of organic, inorganic, and biochemical reactions. Chemical synthesis and the modern methods of computation and instrumental analytical chemistry are particularly stressed. (Offered Fall 2017)

CHEM H302 LAB IN CHEMICAL STRUCTURE AND REACTIVITY
Karin Åkerfeldt, Yang Yang
Natural Science (NA)
Two lectures and two laboratory periods. An introduction to the methods of research in chemistry. Inorganic, organic, physical chemistry, and biochemical concepts are integrated in a broad laboratory study of structure and its relationship to chemical reactivity. Physical methods are used in studies of organic, inorganic, and biochemical reactions. Chemical synthesis and the modern methods of instrumental analytical chemistry are particularly stressed.

Instruments such as lasers, the 500 MHz NMR spectrometer, and the mass spectrometer combined with either gas or liquid chromatography are used by students, with faculty supervision. Prerequisite(s): CHEM 225 and 304, or instructor consent. (Typically offered every spring)

CHEM H304 STATISTICAL THERMODYNAMICS AND KINETICS
Joshua Schrier
Natural Science (NA), Quantitative (QU)
A quantitative approach to the description and prediction of behavior in chemical systems. Topics to be covered include: introductory quantum mechanics and energy in molecules, statistical mechanics and energy partitioning, thermodynamics of molecules and larger systems, physical and chemical equilibrium, and chemical kinetics. Systems of interest range from single molecules to complicated condensed-phase macromolecular assemblies; specific experimental examples of single-molecule observation, phase changes in lipids and liquid crystals, and observations of protein folding will be discussed in the context of the course material. (Offered Fall 2017)

CHEM H305 QUANTUM CHEMISTRY
Yang Yang
Natural Science (NA), Quantitative (QU)
Two lectures. The quantum theory of atoms and molecules as applied to problems in molecular structure, computational chemistry, and basic spectroscopic techniques. Emphasis on computer-based solutions and visualization. Prerequisite(s): MATH 121 or 216, or instructor consent. (Typically offered every spring)

CHEM H320 CONCEPTS OF INORGANIC CHEMISTRY
Jessica Stuart
Natural Science (NA)
Three lectures for one-half semester (one-half course credit). An introduction to structure and reactivity of inorganic molecules and materials. Topics include: theories of chemical bonding, symmetries of molecules and solid state materials, acid-base, oxidation-reduction reactions, and structures and nomenclature of coordination complexes. Prerequisite(s): CHEM 225 or instructor consent. (Typically offered every spring)

CHEM H340 MOLECULAR SPECTROSCOPY: THEORETICAL ASPECTS OF BIOLOGICAL NMR SPECTROSCOPY
Staff
Natural Science (NA)
This course develops the main theoretical formalism for understanding modern NMR spectroscopy of biological macromolecules, including proteins and nucleic acids. (Offered occasionally)

CHEM H351 BIOINORGANIC CHEMISTRY
Robert Scarrow
Natural Science (NA)
Three lectures for one-half semester (one-half course credit). Biological cells require metals such as zinc, iron, copper, manganese, and molybdenum; metal-binding abilities of various functional groups within proteins and nucleic acids, metal-based reactivity involved in reaction mechanisms of specific metalloenzymes, and medically-relevant topics such as bioaccumulation and storage of metal ions, the toxicity of heavy metals, and use of metal-containing drugs in treating disease will be discussed. Prerequisite(s): CHEM 320 or instructor consent. (Typically offered every spring)

CHEM H352 TOPICS IN BIOPHYSICAL CHEMISTRY: NMR OF BIOMOLECULES
Staff
Natural Science (NA)
This course will introduce the principles of modern multidimensional NMR spectroscopy as applied to biological macromolecules, focusing on proteins. Theoretical and experimental aspects of NMR spectroscopy for structure determination, investigation of kinetic rate processes, and characterization of molecular interactions will be discussed. (Offered occasionally)

CHEM H353 TOPICS IN MATERIALS SCIENCE
Joshua Schrier
Natural Science (NA)
This course will focus on the structure-property relationship central to the study of materials with specific functions. Structural studies will include bonding, order/disorder, and non-stoichiometry in crystalline and non-crystalline solids. Optical, magnetic and electronic properties will be discussed in the context of non-linear optical materials, ferroelectric and magnetoresistant

materials, as well as superconductors and semiconductors. (Offered Fall 2017)

CHEM H354 SOLID STATE CHEMISTRY
Stephen Podowitz-Thomas
Natural Science (NA)
Three lectures for one-half semester (one-half course credit). An examination of the reactivity of solids. Synthetic techniques and structural analyses will be emphasized. (Typically offered every spring)

CHEM H355 TOPICS IN ADVANCED ORGANIC CHEMISTRY
Mark Hilfiker
Natural Science (NA)
Three lectures. Variable content, depending on the interests of students and faculty. Topics are selected in consultation with students electing the course. Previous topics have been modern synthetic methods, asymmetric synthesis, natural product chemistry, biosynthesis, chemistry of coenzymes, combinatorial approaches to synthesis, free radical chemistry, organic photochemistry, organometallic chemistry. Prerequisite(s): CHEM 222 or instructor consent. (Offered Fall 2017)

CHEM H357 TOPICS IN BIOORGANIC CHEMISTRY
Mark Hilfiker
Natural Science (NA)
The specific content of the course varies, depending on faculty and student interests. The course will focus on organic chemistry as applied to biological systems and related topics. Prerequisite(s): CHEM 225 or instructor consent. (Offered Fall 2017)

CHEM H358 TOPICS IN ENVIRONMENTAL CHEMISTRY: LEAD IN OUR ENVIRONMENT
Robert Scarrow
Natural Science (NA)
Lead is receiving increasing attention as a toxin in the water, soil and paint of our made environment. This course is aimed at understanding the chemistry of lead and how that chemistry has spawned apparently useful products (anti-knock gasoline additives, paints, and water pipes, for instance) that degrade in and contaminate the environment and result in neurological and other impairments through interactions with human biochemistry. Although the primary focus will be on the chemistry, we will also discuss the evidence for public health effects and the various remediation strategies, as well as political debates about governmental, corporate and individual responsibility for engaging in such remediation. Students will be expected to lead and participate in discussions of primary and secondary literature papers and (in weekly homework assignments) to provide written summaries of and responses to these papers. Crosslisted: Chemistry, Environmental Studies Prerequisite(s): Three semesters of chemistry, through CHEM 222, or instructor consent. (Not offered 2017-18)

CHEM H361 RESEARCH TUTORIAL IN PHYSICAL CHEMISTRY
Casey Londergan
Natural Science (NA)
Directed research in physical chemistry, condensed phase chemical physics, and biophysical chemistry, with emphasis on spectroscopic studies of site-specific environmental and conformational dynamics in peptides and proteins. Prerequisite(s): Instructor consent. (Offered Fall 2017)

CHEM H362 RESEARCH TUTORIAL IN THEORETICAL CHEMISTRY
Joshua Schrier
Natural Science (NA)
Directed research in computational and theoretical physical chemistry, with emphasis on development and application of methods for prediction of optical, electronic, and mechanical properties of organic and inorganic semiconductor nanostructures. Prerequisite(s): Instructor consent. (Offered Fall 2017)

CHEM H363 RESEARCH TUTORIAL IN ORGANIC CHEMISTRY
Frances Blase
Natural Science (NA)
Directed research in synthetic organic chemistry, and physical-organic chemistry. Topics include total synthesis of biologically significant molecules, new methods of enantioselective synthesis and the study of organic reaction mechanisms. Prerequisite(s): Instructor consent. (Offered Fall 2017)

CHEM H364 RESEARCH TUTORIAL IN BIOORGANIC CHEMISTRY
Karin Åkerfeldt
Natural Science (NA)

Directed research in bioorganic chemistry. Topics include protein structure-function relationship studies and the design and synthesis of a broad range of peptides, proteins and biologically inspired novel materials. Prerequisite(s): Instructor consent. (Offered Fall 2017)

CHEM H365 RESEARCH TUTORIAL IN BIOINORGANIC CHEMISTRY
Robert Scarrow
Natural Science (NA)
Topics include spectroscopic and kinetic studies of metalloproteins and inorganic coordination compounds. Prerequisite(s): Instructor consent. (Offered Fall 2017)

CHEM H367 RESEARCH TUTORIAL IN BIOLOGICAL CHEMISTRY
Louise Charkoudian
Natural Science (NA)
Topics include synthesis and reactivity of chiral platinum complexes; structural characterization of platinum oligonucleotide complexes by combined multidimensional NMR/computational methods. Prerequisite(s): Instructor consent. (Offered Fall 2017)

CHEM H368 RESEARCH TUTORIAL IN ENVIRONMENTAL CHEMISTRY
Helen White
Natural Science (NA)
Directed research in environmental chemistry, centered in the field of biogeochemistry, a multidisciplinary approach focused at understanding the chemical composition and processes of Earth's biosphere. Prerequisite(s): Instructor consent. (Offered Fall 2017)

CHEM H369 RESEARCH TUTORIAL: MATERIALS SCIENCE
Alexander Norquist
Natural Science (NA)
Topics include synthesis and structural characterization of organically templated microporous materials. Prerequisite(s): Instructor consent. (Offered Fall 2017)

CHEM H390 LABORATORY IN BIOCHEMICAL RESEARCH
Louise Charkoudian
Natural Science (NA)
An introduction to the laboratory concepts and techniques at the chemistry-biology interface including: molecular cloning, protein purification, biophysical spectroscopy, molecular modeling, and biochemical assays. Crosslisted: Chemistry, Biology; Prerequisite(s): BIOL 300A and CHEM 301, or instructor consent. (Offered Spring 2018)

CHEM H391 DEPARTMENTAL SEMINAR
Joshua Schrier
Natural Science (NA)
Presentation and discussion of current research topics in the various areas of chemistry by faculty, students and outside speakers. Seminar will begin at 2:45 p.m. during the second semester. One meeting per week throughout the year (one-half course credit). (Offered Fall 2017)

CHEM H480 INDEPENDENT STUDY
Staff
Natural Science (NA)
(Offered occasionally)