

CHEMISTRY

Department Website:

<https://www.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.

Haverford's Institutional Learning Goals are available on the President's website, at <http://hav.to/learninggoals>.

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 H113 (Structure and Bonding), followed by CHEM H114 (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 H115, which includes the CHEM H111 lecture and a more investigative, independent lab program, followed by CHEM H112. All students can continue the following year with CHEM H222, a course in organic biological chemistry and CHEM H225, which is focused on organic synthesis. Pre-medical students should continue through at least CHEM H222, and may need to take additional organic or biochemistry courses depending on the requirements of medical schools.

The Chemistry Department also occasionally offers a 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 H301, CHEM H302 and CHEM H303) 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 receive 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 H26x and CHEM H36x) courses during the academic year, and most majors do both. Typically two to seven 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 includes 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 external sources as well as substantial internal support from the College. Students are also encouraged and enabled 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.

Major Requirements

The core required courses are:

- four semesters of introductory and organic chemistry: CHEM H111, CHEM H113 OR CHEM H115, CHEM H112 OR CHEM H114, CHEM H222, and CHEM H225.
- two semesters of advanced integrative chemistry laboratory ("Superlab"): CHEM H301 and CHEM H302.
- one semester of physical chemistry: CHEM H304 or CHEM H305.
- one semester of senior research tutorials: CHEM 36x or CHEM H380.
- two half-semester courses in inorganic chemistry: CHEM H320 and one of CHEM H351, CHEM H353, or CHEM H354.
- Departmental Seminar: CHEM H391 (a half credit course spread over two semesters).

Chemistry majors must also complete:

- one semester of additional advanced chemistry courses numbered CHEM H304-CHEM H358.
- one semester of math (MATH H118 or above).
- two semesters of either introductory physics (PHYS H101/PHYS H102 or PHYS H105/PHYS H106) or biology (BIOL H200).

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 H304 and CHEM H305); for ACS-certified majors these courses do not fulfill the additional advanced course requirement.
- two semesters of introductory physics (PHYS H101/PHYS H102 or PHYS H105/PHYS H106).
- one semester of biochemistry, which can be BIOL H200 (second semester), two half-semester courses from CHEM H351, CHEM H352, CHEM H357 and CHEM H359, or equivalent, such as Bryn Mawr CHEM B242 or higher.

Senior Project

The senior project in chemistry has two major components. First, all seniors enroll in CHEM H391 Departmental 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 H36x designation. CHEM H36x 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 (the "senior thesis" at the end of their spring semester detailing their work in the Senior Project.

CHEM H391 exposes students to chemistry through talks by chemists from other institutions and provides enrolled students with opportunities to present their own work formally. Each student prepares and delivers both an oral and poster presentation. The oral presentations occur throughout the academic year, and 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 H301/CHEM H302 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 research efforts, the quality of the senior thesis, and student participation in senior seminar. The text below conveys our expectations for the research experience:

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 all 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 for internal purposes. 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 and 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 H36x) 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.

Minor Requirements

- Four semesters of introductory and organic chemistry: CHEM H111, CHEM H113 OR CHEM H115, CHEM H112 OR CHEM H114, CHEM H222, and CHEM H225.
- One semester of physical chemistry: CHEM H304 or CHEM H305.
- One semester of advanced chemistry chosen from courses numbered between CHEM H301 and CHEM H369.

Students must take at least three of the courses for the chemistry minor at Haverford College. The Departmental Seminar (CHEM H391) is not required, but recommended.

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.

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, and a biologically flavored version

of the major for biochemistry concentrators.

Biochemistry concentrators can enroll in either CHEM H303 or BIOL H300 / BIOL H301 as one of their junior “Superlab” semesters: these are integrated laboratory courses in biochemistry and biology, respectively. Biochemistry concentrators also take advanced electives offered by the Biology department.

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 H112, CHEM H150 and CHEM H358.

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 Neuroscience advisory committee in order to declare the minor.

Scientific Computing Concentration

The Concentration in Scientific Computing gives students an opportunity to develop a working knowledge of 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 H304, CHEM H305, and CHEM H361 or CHEM H362; students are also encouraged to enroll in CHEM B322 when it is offered at Bryn Mawr College. Scientific Computing concentrators in the Chemistry Department typically do senior thesis research with a strong computational focus.

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 was the first liberal arts college in the world to enter into

such an agreement with an Ivy League engineering program. 4+1 programs of particular synergy with the Chemistry major include Bioengineering, Materials Science, and Nanotechnology.

Study Abroad

Chemistry majors wishing to study abroad during the junior year should confer with their faculty advisors: such students typically take at least one chemistry or biochemistry course per semester at the foreign institution. The Chemistry Department has currently approved and active international study abroad programs at Oxford University (England), University College London (England), University of Melbourne (Australia), 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), among other programs.

After Graduation

About one third of Haverford's chemistry majors enter top-ranked graduate programs leading to a Ph.D., and approximately 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

Frances Rose Blase

Associate Professor of Chemistry

Lou Charkoudian

Associate Professor of Chemistry

Clyde Daly

Assistant Professor of Chemistry

Mark Hilfiker

Visiting Assistant Professor of Chemistry

Bashkim Kokona

Visiting Assistant Professor of Chemistry

Casey Londergan

Professor of Chemistry

Kelly Matz

General Chemistry Laboratory Instructor and Coordinator

Alexander Norquist

Professor of Chemistry

Robert Scarrow

Professor and Chair of Chemistry

Paul Spoons

Visiting Assistant Professor of Chemistry

Mark Stein

Organic Chemistry Instructor

Kristina Streu

Visiting Assistant Professor of Chemistry

Helen White

Associate Provost for Curricular Development and Research; Professor of Chemistry and Environmental Studies

Karin Åkerfeldt

Professor Emeritus of Chemistry

Affiliated Faculty

Amy Cooke

Assistant Professor of Biology

Robert Fairman

Professor of Biology

Rachel Hoang

Associate Professor of Biology

Seol Hee Im

Visiting Assistant Professor of Biology

Roshan Jain

Assistant Professor of Biology

Karl Johnson

Professor and Chair of Biology

Sara Mathieson

Assistant Professor of Computer Science; Coordinator of Scientific Computing

Eric Miller

Assistant Professor of Biology

Kristen Whalen

Assistant Professor of Biology

Courses

CHEM H111 CHEMICAL STRUCTURE AND BONDING (1.0 Credit)

Kelly Matz, Kristina Streu

Division: Natural Science; Quantitative

Domain(s): C: Physical and Natural Processes

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.

(Offered: Fall 2021; **typically offered:** Every Fall)

CHEM H112 CHEMICAL DYNAMICS (1.0 Credit)

Alexander Norquist, Kelly Matz, Paul Spoons

Division: Natural Science; Quantitative

Domain(s): C: Physical and Natural Processes

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.

One hour recitation times to be announced.

Prerequisite(s): Completion of, or prior placement into CHEM 111 or CHEM 115, or recommendation of CHEM 113 instructor

(Offered: Spring 2022; **typically offered:** Every Spring)

CHEM H113 INTENSIVE: CHEMICAL STRUCTURE AND BONDING (1.0 Credit)

Frances Rose Blase, Kelly Matz, Staff

Division: Natural Science; Quantitative

Domain(s): C: Physical and Natural Processes

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. Prerequisite(s): Placement by the Chemistry Department.

(Offered: Fall 2021; **typically offered:** Every Fall)

CHEM H114 INTENSIVE: CHEMICAL DYNAMICS (1.0 Credit)

Clyde Daly, Kelly Matz, Paul Spoons

Division: Natural Science; Quantitative

Domain(s): C: Physical and Natural Processes

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): CHEM 113 or recommendation of CHEM 111 instructor

(Offered: Spring 2022; **typically offered:** Every Spring)

CHEM H115 CHEMICAL STRUCTURE AND BONDING WITH INQUIRY LAB (1.0 Credit)

Kristina Streu, Robert Scarrow

Division: Natural Science

Domain(s): C: Physical and Natural Processes

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. Prerequisite(s): Placement by the Chemistry Department

(Typically offered: Every Fall)

CHEM H150 INTRODUCTION TO OCEANOGRAPHY (1.0 Credit)

Helen White

Division: Natural Science

Domain(s): C: Physical and Natural Processes

The oceans are one of the principal agents controlling global change, and are linked to nearly all of the biological, chemical, geological, and ecological systems on our planet's surface. In this course we will examine these systems and the impact of humans upon them.

(Typically offered: Occasionally)

CHEM H222 ORGANIC BIOLOGICAL CHEMISTRY (1.0 Credit)

Lou Charkoudian, Mark Stein

Division: Natural Science

Domain(s): C: Physical and Natural Processes

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. Prerequisite(s): CHEM H111 or CHEM H113 or CHEM H115; and CHEM 104 or CHEM H112 or CHEM H114. Alternatively, students who have taken a two semester General Chemistry course elsewhere (for instance, CHEM B103 and CHEM B104) must, prior to the start of CHEM H222, demonstrate knowledge (by a self-scheduled exam) of common organic functional group structures and spectroscopic methods (as covered by CHEM H111, CHEM H113 and CHEM H115); students should contact the Department Chair the instructor

immediately after preregistration to obtain access to a self-guided course centered on these topics.
(**Offered:** Fall 2021; **typically offered:** Every Fall)

CHEM H225 ORGANIC REACTIONS AND SYNTHESIS (1.0 Credit)

Frances Rose Blase, Mark Stein

Division: Natural Science

Domain(s): C: Physical and Natural Processes

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. Prerequisite: CHEM H222 Recitation Options: Th 9-10 or F 1-2.
(**Offered:** Spring 2022; **typically offered:** Every Spring)

CHEM H261 RESEARCH TUTORIAL IN PHYSICAL CHEMISTRY (0.5 Credit)

Casey Londergan

Division: Natural Science

Domain(s): C: Physical and Natural Processes

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: interested students should discuss possible enrollment with the instructor.
(**Offered:** Fall 2021, Spring 2022; **typically offered:** Every Semester)

CHEM H262 RESEARCH TUTORIAL IN THEORETICAL CHEMISTRY (0.5 Credit)

Clyde Daly

Division: Natural Science

Domain(s): C: Physical and Natural Processes

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 2021, Spring 2022; **typically offered:** Every Semester)

CHEM H263 RESEARCH TUTORIAL IN ORGANIC CHEMISTRY (0.5 Credit)

Paul Spoors

Division: Natural Science

Domain(s): C: Physical and Natural Processes

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 2021, Spring 2022; **typically offered:** Every Semester)

CHEM H264 RESEARCH TUTORIAL IN BIOORGANIC CHEMISTRY (0.5 Credit)

Karin Åkerfeldt

Division: Natural Science

Domain(s): C: Physical and Natural Processes

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 (0.5 Credit)

Robert Scarrow

Division: Natural Science

Domain(s): C: Physical and Natural Processes

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.) This course is graded universal P/F in which no numerical grade is assigned. Prerequisite(s): Instructor consent (requires prior discussion of, and agreement on, type of research to be pursued; this assures that necessary resources will be available and that the student's knowledge of chemistry is sufficient to safely and effectively carry out the research). Interested students should reach out to the instructor to discuss potential enrollment
(**Offered:** Fall 2021, Spring 2022; **typically offered:** Every Year)

CHEM H267 RESEARCH TUTORIAL IN BIOLOGICAL CHEMISTRY (0.5 Credit)

Lou Charkoudian

One-half credit course for the year designed for students interested in the chemistry research experience in natural product biosynthesis. (Not open to seniors.) This course is graded universal P/F in which no numerical grade is assigned. Prerequisite(s): Instructor consent
(**Offered:** Fall 2021, Spring 2022; **typically offered:** Every Semester)

CHEM H268 RESEARCH TUTORIAL IN ENVIRONMENTAL CHEMISTRY (0.5 Credit)*Helen White***Division:** Natural Science**Domain(s):** C: Physical and Natural Processes

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 2021, Spring 2022; **typically offered:** Every Semester)

CHEM H269 RESEARCH TUTORIAL IN MATERIALS SCIENCE (0.5 Credit)*Alexander Norquist***Division:** Natural Science**Domain(s):** C: Physical and Natural Processes

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 2021, Spring 2022; **typically offered:** Every Semester)

CHEM H301 LAB IN CHEMICAL STRUCTURE AND REACTIVITY (1.0 Credit)*Paul Spoor***Division:** Natural Science**Domain(s):** C: Physical and Natural Processes

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 2021; **typically offered:** Every Fall)

CHEM H302 LAB IN CHEMICAL STRUCTURE AND REACTIVITY (1.0 Credit)*Kristina Streu, Staff***Division:** Natural Science**Domain(s):** C: Physical and Natural Processes

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 H225 and either CHEM H304, or CHEM H305 (which may be taken concurrently)

(Offered: Spring 2022; **typically offered:** Every Spring)

CHEM H303 LABORATORY IN BIOCHEMICAL RESEARCH (1.0 Credit)*Kristina Streu, Lou Charkoudian***Division:** Natural Science**Domain(s):** C: Physical and Natural Processes

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): CHEM H225

(Offered: Spring 2022; **typically offered:** Every Spring)

CHEM H304 STATISTICAL THERMODYNAMICS AND KINETICS (1.0 Credit)*Clyde Daly***Division:** Natural Science; Quantitative**Domain(s):** C: Physical and Natural Processes

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. Prerequisite(s): MATH H118 (or placement beyond MATH H118) and either CHEM H104 or CHEM H112 or CHEM H114

(Offered: Fall 2021; **typically offered:** Every Fall)

CHEM H305 QUANTUM CHEMISTRY (1.0 Credit)*Clyde Daly***Division:** Natural Science; Quantitative**Domain(s):** C: Physical and Natural Processes

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
(**Offered:** Spring 2022; **typically offered:** Every Spring)

CHEM H310 SEMINAR IN THE SOCIAL RELEVANCE OF CHEMISTRY (0.5 Credit)

Helen White

Division: Natural Science

Domain(s): C: Physical and Natural Processes

This seminar will explore, articulate, and discuss the influence that Chemistry and society have on each other. Participants will develop awareness of the historical, political and cultural context of western science, with specific attention to how chemistry affects, and is affected by, the exclusion of people and ideas based on race, ethnicity, ability, socioeconomic status, and other identities. Participants will connect these topics of study to their current roles at Haverford and future careers. Pre-requisite(s): One semester of CHEM 225 or a declared Chemistry major Lottery Preference: Declared Majors: Seniors, then Juniors
(**Offered:** Fall 2021; **typically offered:** Every Fall)

CHEM H320 CONCEPTS OF INORGANIC CHEMISTRY (0.5 Credit)

Robert Scarrow

Division: Natural Science

Domain(s): C: Physical and Natural Processes

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 H225
(**Offered:** Spring 2022; **typically offered:** Every Spring)

CHEM H351 BIOINORGANIC CHEMISTRY (0.5 Credit)

Division: Natural Science

Domain(s): C: Physical and Natural Processes

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 H222 and either CHEM H320 or BIOLH201

(**Offered:** Spring 2022; **typically offered:** Every Spring)

CHEM H352 TOPICS IN BIOPHYSICAL CHEMISTRY: BIOMOLECULAR MODELING (0.5 Credit)

Staff

Division: Natural Science

Domain(s): C: Physical and Natural Processes

This course will introduce the fundamentals of biomolecular modeling. Students will gain a conceptual understanding of computational modeling techniques and practical experience using contemporary computational methods. While a broad range of methods will be introduced, we will cover molecular dynamics (MD) simulations in depth. Prerequisite(s): Chem H304 or equivalent (depending on material), or instructor consent.

(**Offered:** Fall 2021; **typically offered:** Occasionally)

CHEM H353 TOPICS IN MATERIAL SCIENCE: ENERGY TECHNOLOGY (0.5 Credit)

Staff

Division: Natural Science

Domain(s): C: Physical and Natural Processes

The focus of this course will be energy technology. (**Offered:** Spring 2022; **typically offered:** Occasionally)

CHEM H354 SOLID STATE CHEMISTRY (0.5 Credit)

Alexander Norquist

Division: Natural Science

Domain(s): C: Physical and Natural Processes

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: ORGANIC REACTIONS AND SYNTHESIS II (0.5 Credit)

Paul Spoors

Division: Natural Science

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): Chemistry H225.
(**Offered:** Spring 2022; **typically offered:** Occasionally)

CHEM H357 TOPICS IN BIOORGANIC CHEMISTRY (0.5 Credit)*Mark Hilfiker***Division:** Natural Science**Domain(s):** C: Physical and Natural Processes

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 2021; **typically offered:** Occasionally)

CHEM H358 TOPICS IN ENVIRONMENTAL CHEMISTRY: HEAVY METALS IN OUR ENVIRONMENT (0.5 Credit)*Robert Scarrow***Division:** Natural Science

Three lectures for one-half semester (one-half course credit). This course will examine chemical processes that occur in natural waters, soils and the atmosphere. Specific topics will be chosen with input from enrolled students, who will be expected to share in discussion leadership. Prerequisite(s): CHEM H222 (or other organic chemistry course such as CHEM B211)

(Typically offered: Occasionally)

CHEM H361 SENIOR RESEARCH TUTORIAL IN PHYSICAL CHEMISTRY (1.0 Credit)*Casey Londergan***Division:** Natural Science

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 2021; **typically offered:** Every Semester)

CHEM H362 SENIOR RESEARCH TUTORIAL IN THEORETICAL CHEMISTRY (1.0 Credit)*Clyde Daly***Division:** Natural Science

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 2021; **typically offered:** Every Semester)

CHEM H363 SENIOR RESEARCH TUTORIAL IN ORGANIC CHEMISTRY (1.0 Credit)*Paul Spoor***Division:** Natural Science

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 2021; **typically offered:** Every Semester)

CHEM H364 SENIOR RESEARCH TUTORIAL IN BIOORGANIC CHEMISTRY (1.0 Credit)*Karin Åkerfeldt***Division:** Natural Science

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

(Typically offered: Every Semester)

CHEM H365 SENIOR RESEARCH TUTORIAL IN BIOINORGANIC CHEMISTRY (1.0 Credit)*Robert Scarrow***Division:** Natural Science

Directed research in bioinorganic and coordination chemistry. Topics include synthesis and spectroscopic and kinetic studies of inorganic coordination compounds that can aid in understanding the chemistry of metalloproteins. Prerequisite(s): Instructor consent

(Offered: Fall 2021; **typically offered:** Every Semester)

CHEM H367 SENIOR RESEARCH TUTORIAL IN BIOLOGICAL CHEMISTRY (1.0 Credit)*Lou Charkoudian***Division:** Natural Science

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 2021; **typically offered:** Every Semester)

CHEM H368 SENIOR RESEARCH TUTORIAL IN ENVIRONMENTAL CHEMISTRY (1.0 Credit)*Helen White***Division:** Natural Science

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 2021; **typically offered:** Every Semester)

CHEM H369 SENIOR RESEARCH TUTORIAL IN MATERIALS SCIENCE (1.0 Credit)

Alexander Norquist, Staff

Division: Natural Science

Domain(s): C: Physical and Natural Processes

Directed research in inorganic materials chemistry. Topics include synthesis and structural characterization of organically templated microporous materials. Prerequisite(s): Instructor consent

(Offered: Spring 2022; **typically offered:** Every Semester)

CHEM H391 CHEMISTRY DEPARTMENTAL SEMINAR (0.5 Credit)

Robert Scarrow

Presentation and discussion of current research topics in the various areas of chemistry by faculty, students and outside speakers. One meeting per week throughout the year (one-half course credit). This course is graded universal P/F in which no numerical grade is assigned. Prerequisite(s): concurrent enrollment in a research tutorial course (CHEM H361 to CHEM H369, or equivalent).

(Offered: Fall 2021, Spring 2022; **typically offered:** Every Semester)

CHEM H480 INDEPENDENT STUDY (1.0 Credit)

Staff

Division: Natural Science

Independent Study

(Offered: Fall 2021, Spring 2022; **typically offered:** Every Spring)