

# CHEMISTRY

<https://chemistry.jhu.edu/>

The Department of Chemistry, in conjunction with other departments of the university, offers a broad education and the opportunity to do research in chemistry and related fields. The great diversity of the field of chemistry, ranging between physics and biology, is reflected in the research interests of the faculty. Undergraduate chemistry majors usually go on to graduate study in chemistry, chemical engineering, biology, oceanography, geochemistry, biophysics, environmental sciences, or medicine, while others enter the chemical industry. The Ph.D. in chemistry leads to professional careers in colleges and universities, research institutes, industry, and government laboratories.

## Facilities

The department is well-equipped with instrumentation, both shared and in individual faculty research laboratories, to perform modern chemical research. The Departmental Instrumentation Facility houses the following pieces of major instrumentation:

- Bruker Avance 400 MHz FT-NMR spectrometers (2), one located in the Instrumentation Facility in Remsen Hall and the other on the first floor of the New Chemistry Building.
- Bruker Avance 300 MHz FT-NMR spectrometer.
- Bruker Avance III 400 MHz FT-NMR spectrometer and Fourier 300 FT-NMR spectrometer with an automatic sample changer are located in the undergraduate teaching laboratory.
- Bruker Neo 500MHz Solid State NMR Spectrometer
- VG70S magnetic sector mass spectrometer, with EI, and CI ionization.
- VG70SE magnetic sector mass spectrometer, with FAB ionization.
- Finnigan LCQ Fleet ion trap Mass Spectrometer with ESI ionization and HPLC inlet.
- Waters Acquity / Xevo G2 UPLC-Q-ToF MS with ESI and APCI ionisation.
- Waters XevoG2-S – Standalone ESI mass spectrometer (can be equipped with ASAP)
- Thermo QEHF-X Orbitrap Mass Spectrometer with Ultimate 3000 NanoLC
- Bruker EMX EPR spectrometer equipped with a liquid helium cryostat and variable temperature controller.
- Jasco P-1010 polarimeter.
- SuperNova X-ray diffractometer (dual hi-flux micro-focus Mo and Cu sources) with Atlas CCD area detector (located on the second floor of the new chemistry building).
- Shimadzu QP2010SE GC-MS.
- Bruker AutoFlex Max Maldi Tof.
- Rigaku XtaLAB Synergy R equipped with a rotating-anode X-ray source (Cu K $\alpha$  radiation) and HyPix-6000HE detector (located on the second floor of the new chemistry building).

## NMR Facility

The NMR facility based in Remsen Hall consists of the three walk-up NMR (two in Remsen, one in the New Chemistry Building), an EPR and FTIR spectrometers, as well as a Polarimeter. In 2013, two new NMR spectrometers were purchased as part of the new Undergraduate Teaching Laboratories: a Bruker Avance III 400 MHz FT-NMR spectrometer and a Fourier 300 FT-NMR spectrometer with an

automatic sample changer that can hold up to 60 samples. These can be used for research during the summer months when undergraduate labs are not in session. Upon checkout by the NMR facility manager, students are allowed to operate these instruments.

NMR spectrometers suitable for studies of biological macromolecules are located in the Biomolecular NMR Center, located in an underground facility in front of the New Chemistry Building. This center is a joint initiative of the departments of biology, biophysics, chemistry, and materials science, with additional collaboration from the School of Medicine's departments of biochemistry and pharmacology. The instruments include 500, 600, and 800 MHz FT-NMR spectrometers. Scheduling for these spectrometers is handled by the center.

## Mass Spectrometry Facility

A variety of different mass spectral techniques are available in the Mass Spectrometry Facility. High-resolution mass spectra of submitted samples are obtained on a service basis by a staff member using a magnetic sector instrument equipped with EI, CI, and FAB ionization methods. MALDI-TOF, GC/MS, and electrospray instruments are also available and operated by students and researchers following training by the facility staff.

## X-ray Crystallography Facility

The X-ray Crystallography Facility is operated by a staff member. The facility is mainly concerned with the X-ray structure determinations of small molecules of new organic, inorganic, organometallic, and coordination compounds. Additionally, the dual-source Supernova diffractometer can perform crystal screening and collect data for protein crystals, and can collect high-quality data for tiny crystals.

## Physical Sciences Machine Shop

The department shares the use of the Physical Sciences Machine Shop, located in Bloomberg Hall, with the Department of Physics and Astronomy. Electronics construction and repair is handled by a staff member in the Departmental Instrumentation Facility.

A department computer lab with Macintosh and Windows PC computers is available for undergraduate and graduate students to use.

In addition to the departmental instrumentation, individual research groups have acquired or constructed numerous pieces of specialized research instrumentation. A wide variety of laser systems, including Ar ion, Nd:YAG, excimer, dye lasers, and optical parametric oscillators are operational in individual faculty laboratories. Custom-built apparatuses include negative ion photoelectron spectrometers, UV and IR cavity ring-down spectrometers, electron energy-loss spectrometers, time-of-flight and magnetic mass spectrometers, molecular beam apparatus, UHV surface analysis apparatus, atomic-force microscopes, nanophase material generators, and a nanosecond time-resolved IR spectrometer.

## PARADIM

The crystal growth facility of the Platform for the Accelerated Realization, Analysis, and Discovery of Interface Materials is located in Bloomberg Hall at Johns Hopkins University. For more information, including instructions for access, please visit the PARADIM website.

## Undergraduate Program

Programs for undergraduate majors can be tailored to individual interests so that a major in chemistry is excellent preparation not only for further work in chemistry, but also for any field that rests on a chemical



foundation. It is a good choice for a premedical student interested in medical research.

## Programs

- Chemistry, Bachelor of Science (<https://e-catalogue.jhu.edu/arts-sciences/full-time-residential-programs/degree-programs/chemistry/chemistry-bachelor-arts/>)
- Chemistry, Bachelor of Science/Master of Science (<https://e-catalogue.jhu.edu/arts-sciences/full-time-residential-programs/degree-programs/chemistry/chemistry-bachelors-masters-combined/>)
- Chemistry, PhD (<https://e-catalogue.jhu.edu/arts-sciences/full-time-residential-programs/degree-programs/chemistry/chemistry-phd/>)

For current course information and registration go to <https://sis.jhu.edu/classes/>

## Courses

### AS.030.101. Introductory Chemistry I. 3 Credits.

The fundamental principles of chemistry, including atomic and molecular structure, bonding, elementary thermodynamics, equilibrium and acids and bases, are introduced in this course. Can be taken with Introductory Chemistry Laboratory – I unless lab has been previously completed.

Note: Students taking this course and the laboratory 030.105 may not take any other course in the summer sessions and should devote full time to these subjects. High school physics and calculus are strongly recommended as prerequisites. First and second terms must be taken in sequence. Students not enrolled in college (unless they are rising freshmen) may not take this course. Course is offered in Summer and Fall terms only.

Distribution Area: Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

### AS.030.102. Introductory Chemistry II. 3 Credits.

Continuation of AS.030.101 emphasizing chemical kinetics, chemical bonding. Topics: energy levels and wave functions for particle-in-a-box and hydrogen atom and approximate wave functions for molecules including introduction to hybrid orbitals. Course is offered in Spring and Summer terms only.

**Prerequisite(s):** Students enrolled in AS.030.103 may not enroll in or receive credit for AS.030.102.; AS.030.101. C- or better is required for all pre-requisite courses.

Distribution Area: Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

### AS.030.103. Applied Chemical Equilibrium and Reactivity w/lab. 4 Credits.

This course is designed for students who have scored a 4 or 5 on the AP Chemistry Exam or who have scored a 6 or 7 HL IB Chemistry Exam. This course will review an advanced introductory chemistry sequence in a single semester. Chemical equilibrium, reactivity and bonding will be covered. These topics will be explored through laboratory experiments and problem solving, and discussing these principles in the context of current research. For details on chemistry placement and exam credit policies, please see [http://www.advising.jhu.edu/placement\\_chemistry.php](http://www.advising.jhu.edu/placement_chemistry.php) Students who have previously enrolled in AS.030.101 or AS.030.105 may not earn credit for AS.030.103 and students enrolled in AS.030.103 may not enroll in or receive credit for AS.030.102/AS.030.106.

**Prerequisite(s):** Click here to access the Laboratory Safety Introductory Course (<https://johnshopkins.csod.com/ui/lms-learning-details/app/curriculum/66847e20-c695-4e54-a6be-8c94465b8a70/>)

Distribution Area: Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

### AS.030.104. Applications of Chemistry in Medicine. 1 Credit.

Chemistry is one of the oldest scientific disciplines through major contributions have been made in various fields such as health care, medicine, pharmaceutical sciences, materials and polymer science and forensic chemistry, to name a few. The development of new drugs involves chemical analysis and synthesis of new compounds. Chemistry also plays a vital role in the development and growth of several consumer-based industries such as pigments and paints, pharmaceuticals, cosmetics and oil and natural gas. In this program, students will be introduced to applications of chemistry in medicine and pharmaceutical sciences. Prerequisite: Background in chemistry and biology.

AS Foundational Abilities: Science and Data (FA2)

### AS.030.105. Introductory Chemistry Laboratory I. 1 Credit.

The experiments in this course are designed to support the learning of topics taught in AS.030.101 alongside developing your basic laboratory skills. They will provide students with a visual understanding of some of the key concepts of general chemistry and practice applying concepts to experimental procedures, observations, and results. Open only to those who are registered for or have successfully completed Introductory Chemistry 030.101. Course is offered in Summer and Fall terms only.

**Prerequisite(s):** Students enrolled in AS.030.105 may not enroll in AS.030.115, AS.030.103, or AS.030.107.; Click here to access the Laboratory Safety Introductory Course (<https://johnshopkins.csod.com/ui/lms-learning-details/app/curriculum/66847e20-c695-4e54-a6be-8c94465b8a70/>); Students may take AS.030.101 at the same time as or complete it before enrolling in AS.030.105.

Distribution Area: Natural Sciences

AS Foundational Abilities: Science and Data (FA2)



**AS.030.106. Introductory Chemistry Laboratory II. 1 Credit.**

Laboratory work includes some quantitative analysis and the measurement of physical properties. Open only to those who are registered for or have completed Introductory Chemistry II (AS.030.102). Permission required for pre-college students. Course offered in Spring and Summer terms only.

**Prerequisite(s):** Students enrolled in AS.030.103 may not enroll in or receive credit for AS.030.106.; Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter ASEN in the Search Box to access the proper course. Click here to access the Laboratory Safety Introductory Course (<https://johnshopkins.csod.com/ui/lms-learning-details/app/curriculum/66847e20-c695-4e54-a6be-8c94465b8a70/>); AS.030.105 AND AS.030.101

Distribution Area: Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

**AS.030.109. RECAP – Reviewing Essential Chemistry in Advanced Preparation. 1 Credit.**

This course is designed to bridge the gap between Introductory Chemistry II and Organic Chemistry I. It focuses on reinforcing key concepts from Introductory Chemistry I and II that are essential for success in Organic Chemistry I and have been identified by current teaching faculty as areas of weakness for students. The course will address common areas of difficulty and provide students with a solid foundation to excel in their upcoming organic chemistry studies.

This course is designed so that students have the time to do review the necessary topics that will reappear while getting a more in-depth understanding of these introductory chemistry topics. There will be an emphasis on conceptualization, so students not only have a strong understanding but also the ability to apply and synthesize information based on their knowledge.

**Prerequisite(s):** Students must have completed AS.030.102 to enroll in AS.030.109.

AS Foundational Abilities: Science and Data (FA2)

**AS.030.111. Reading and Interpreting Scientific Studies. 3 Credits.**

Many controversial health claims have entered the public consciousness over the years. Claims made by popular media are often conflicting and it can be difficult to trust their validity without directly examining their sources: data produced in scientific journals. However, the unfamiliar structure and technical jargon of these publications often act as a roadblock to understanding. This course aims to introduce common research methods and approaches and provide strategies for approaching research articles and interpreting their results using popular scientific topics as examples. Students will examine the biochemistry behind controversial topics such as CBD supplements, dieting, and gene editing and more importantly, build the skills to determine for themselves the validity of some of the many claims that enter the public consciousness.

Distribution Area: Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

**AS.030.205. Introductory Organic Chemistry I. 4 Credits.**

The fundamental chemistry of the compounds of carbon. Methods of structure determination and synthesis. The mechanisms of typical organic reactions and the relations between physical and chemical properties and structures. Course offered only in Summer and Fall terms.

**Prerequisite(s):** AS.030.102 OR AS.030.103

Distribution Area: Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

**AS.030.206. Organic Chemistry II. 4 Credits.**

Continuation of AS.030.205 Organic Chemistry I with special emphasis on organic synthesis and related synthetic methods. Students may not simultaneously enroll for AS.030.212 and AS.030.206. Course only offered in Spring and Summer terms.

**Prerequisite(s):** AS.030.205

**Corequisite(s):** Students may not simultaneously enroll for AS.030.212 and AS.030.206.

Distribution Area: Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

**AS.030.212. Honors Organic Chemistry II. 4 Credits.**

Second semester undergraduate organic chemistry from a more advanced perspective, emphasizing connections to modern examples from biochemistry (protein and DNA structure, chemical logic of metabolism, enzyme mechanisms), catalysis, materials (polymer synthesis, supramolecular chemistry), medicine (drug structure and function) and more. The standard topics of second semester organic chemistry (e.g. reactivity of aromatic and carbonyl-containing molecules) will all be covered, but amplified and enriched with topics as noted.

Students may not simultaneously enroll in AS.030.212 and AS.030.206.

Prereq: Must receive a B+ or better in the first semester (AS.030.205)

**Prerequisite(s):** Must receive a B+ or better in the first semester (AS.030.205)

Distribution Area: Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

**AS.030.225. Introductory Organic Chemistry Laboratory. 3 Credits.**

Laboratory work includes fundamental laboratory techniques and preparation of representative organic compounds. Open only to those who are registered for or have completed Introductory Organic Chemistry. Note: This one-semester course is offered each term. Introductory Organic Chemistry I/II requires one semester of the laboratory.

**Prerequisite(s):** Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter ASEN in the Search Box to access the proper course. Click here to access the Laboratory Safety Introductory Course (<https://johnshopkins.csod.com/ui/lms-learning-details/app/curriculum/66847e20-c695-4e54-a6be-8c94465b8a70/>); AS.030.205 AND ((AS.030.102 AND AS.030.106) OR AS.030.103) can be taken prior to enrolling or at the same time as AS.030.225.

**Corequisite(s):** Students may not simultaneously enroll for AS.030.225 and AS.030.227

Distribution Area: Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

**AS.030.227. Chemical Chirality: An Introduction in Organic Chem. Lab, Techniques. 3 Credits.**

This is a project lab designed for Chemistry Majors who are concurrently enrolled in AS.030.205. Techniques for the organic chemistry laboratory including methods of purification, isolation, synthesis, and analysis will be explored through a project focused on chemical chirality. Students may not simultaneously enroll for AS.030.225 and AS.030.227.

**Prerequisite(s):** Click here to access the Laboratory Safety Introductory Course (<https://johnshopkins.csod.com/ui/lms-learning-details/app/curriculum/66847e20-c695-4e54-a6be-8c94465b8a70/>); AS.030.205 may be taken at the same time or prior to enrolling in AS.030.227.

**Corequisite(s):** Students may not simultaneously enroll for AS.030.225 and AS.030.227.

Distribution Area: Natural Sciences

AS Foundational Abilities: Science and Data (FA2)



**AS.030.228. Intermediate Organic Chemistry Laboratory. 3 Credits.**

Lab skills already acquired in AS.030.225 will be further developed for synthesis, isolation, purification, and identification of organic compounds. Spectroscopic techniques, applications will be emphasized. Recommended Course Background: AS.030.225

**Prerequisite(s):** Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter ASEN in the Search Box to access the proper course. Click here to access the Laboratory Safety Introductory Course (<https://johnshopkins.csod.com/ui/lms-learning-details/app/curriculum/66847e20-c695-4e54-a6be-8c94465b8a70/>); AS.030.205 AND (AS.030.225 OR AS.030.227); AS.030.206 OR AS.030.212 can be taken prior to enrolling in AS.030.228 OR at the same time as AS.030.228. Distribution Area: Natural Sciences

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.245. Quantitative Analytical Laboratory. 3 Credits.**

This is a 3 credit lab that will serve as an introduction into analytical techniques and quantitative methods. There will be a 1 hour of pre-lab lecture component to this course to discuss the lab for that day.

**Prerequisite(s):** (AS.030.102 OR AS.030.103) AND AS.030.205 Distribution Area: Natural Sciences AS Foundational Abilities: Writing and Communication (FA1), Science and Data (FA2), Projects and Methods (FA6) Writing Intensive

**AS.030.246. Quantitative Analytical Chemistry and Spectroscopy lab. 3 Credits.**

The Quantitative Analytical and Spectroscopy lab will focus on learning to accurately make quantitative measurements using a variety of analytical techniques and instruments. Students will gain expertise in preparing samples, running samples on various instruments and analyzing and interpreting their results. The course is writing intensive and will include review of current literature related to the content, as well as an independent project and a final exam.

Distribution Area: Natural Sciences AS Foundational Abilities: Writing and Communication (FA1), Science and Data (FA2), Projects and Methods (FA6) Writing Intensive

**AS.030.301. Physical Chemistry I. 3 Credits.**

The laws of thermodynamics, their statistical foundation, and their application to chemical phenomena. Students should have knowledge of general physics, general chemistry, and calculus (two semesters recommended). Freshmen by permission only.

Distribution Area: Natural Sciences AS Foundational Abilities: Science and Data (FA2), Ethics and Foundations (FA5)

**AS.030.302. Physical Chemistry II. 3 Credits.**

Introduction to quantum mechanics, its application to simple problems for which classical mechanics fails. Topics: Harmonic oscillator, hydrogen atom, very approximate treatments of atoms and molecules, and theoretical basis for spectroscopy. Recommended Course Background: AS.030.301

Distribution Area: Natural Sciences AS Foundational Abilities: Science and Data (FA2)

**AS.030.305. Physical Chemistry Instrumentation Laboratory I. 3 Credits.**

This course is designed to illustrate the principles of physical chemistry and to introduce the student to techniques and instruments used in modern chemical research. Chemistry majors are expected to take this sequence of courses, rather than AS.030.307. Chemistry majors only.

**Prerequisite(s):** Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter ASEN in the Search Box to access the proper course. Click here to access the Laboratory Safety Introductory Course (<https://johnshopkins.csod.com/ui/lms-learning-details/app/curriculum/66847e20-c695-4e54-a6be-8c94465b8a70/>)

Distribution Area: Natural Sciences AS Foundational Abilities: Science and Data (FA2)

**AS.030.306. Physical Chemistry Instrumentation Laboratory II. 3 Credits.**

Designed to illustrate the principles of physical chemistry, introduce the student to spectroscopic techniques and instruments used in modern chemical research. Chemistry majors are expected to take this course rather than AS.030.307.

**Prerequisite(s):** Click here to access the Laboratory Safety Introductory Course (<https://johnshopkins.csod.com/ui/lms-learning-details/app/curriculum/66847e20-c695-4e54-a6be-8c94465b8a70/>); AS.030.301 OR AS.030.302

Distribution Area: Natural Sciences AS Foundational Abilities: Science and Data (FA2)

**AS.030.308. From Maglev to MRI: Fundamentals of Magnetism and Magnetic Materials. 3 Credits.**

This course will introduce students to the atomic origins of magnetism in real materials, with an emphasis on applications across a wide variety of fields. Beginning with a review of the quantum mechanical and chemical considerations that drive magnetic order, we will then explore how existing theoretical models can be used to describe unusual and often useful forms of magnetism. The latter half of the course will focus on the ways in which magnetic materials are commonly synthesized and characterized, and their importance in various electronic and medical applications. Finally, we will discuss recent advancements in the field, as well as the promise of such materials in the development of novel technologies.

**Prerequisite(s):** AS.030.102 AS Foundational Abilities: Science and Data (FA2)

**AS.030.309. Scientific Literacy and Nobel Prize Chemistry. 3 Credits.**

In this class undergraduate students will be challenged to seek the connection between the material learned in class and recent scientific publications in the field. This course aim is to engage students with an organic chemistry background to think critically about major research publications, and to give them the tools to approach scientific literature with curiosity and confidence. Students will have the chance to read selected Nobel Prize winning scientific research from 2022 to 1902, from bioconjugation and click chemistry (2022) to molecular machines (2016), including capstones such as palladium catalyzed cross couplings (2010) to catalysis (2021). The aim is to build up an organic chemistry curriculum that will peak with the exploration of Retrosynthetic Analysis, introduced by E J Corey in 1990. This last concept will allow students to tackle overwhelming natural product synthesis papers, learning how to break down complex structures into simpler building blocks with recognizable reactivity. The introduction of high-stakes chemistry topics into an upper-level course will allow students to ponder on their interests, future studies, or careers in the field.

AS Foundational Abilities: Science and Data (FA2)



**AS.030.310. Introduction to Research in Chemical Sciences (IRCS). 3 Credits.**

Students will learn about the process behind modern chemical research, including the development of hypotheses, experimental design, statistical inference, scientific writing and communication, scientific ethics, and data presentation. Students will learn to become critical consumer of the primary scientific literature. Course will emphasize development of communication of research in the oral and written formats, which will be exercised through a peer-reviewed report, an oral presentation, and a poster presentation. The course has a once-weekly lecture component and also requires that students be working 10 hours per week in a research group pursuing a project of their own. A letter certifying the student is part of a research group and a suitable project has been discussed is required for enrollment to be approved.

Distribution Area: Natural Sciences

AS Foundational Abilities: Writing and Communication (FA1), Science and Data (FA2), Projects and Methods (FA6)

**AS.030.356. Advanced Inorganic Lab. 3 Credits.**

Laboratory designed to illustrate the principles and practice of inorganic chemistry through the synthesis and characterization of transition metal and organometallic compounds. Methods used include vacuum and inert atmosphere techniques. Instrumental approaches and modern spectroscopic techniques are applied to the characterization of compounds generated. It is strongly recommended that students have taken or are taking one of the following courses: AS.030.204, AS.030.442, AS.030.449, or AS.030.472.

**Prerequisite(s):** AS.030.228

Distribution Area: Natural Sciences

AS Foundational Abilities: Writing and Communication (FA1), Science and Data (FA2), Projects and Methods (FA6)

Writing Intensive

**AS.030.403. Optoelectronic Materials and Devices: Synthesis, Spectroscopy, and Applications. 3 Credits.**

This course provides an introduction to the vast chemistry and physics of solid-state materials. The course begins with a fundamental description of bonding in crystalline solids and calculation of electronic band structure. We then extend our discussion to methods for the synthesis of low-dimensional materials and hierarchical structures, including quantum dots (0D), nanowires (1D), graphene and graphene analogs (2D), and thin-film superlattices. An in-depth discussion of spectroscopic and characterization techniques for solid-state materials will follow and focus on some of the foundational studies of quantum devices and cooperative phenomena. At this stage we will describe recent advances in electron-microscopy (e.g. aberration-corrected and energy filtered TEM, atom-probe tomography) that are revolutionizing the structural, compositional, and electronic characterization of materials. The course will conclude with a survey of contemporary topics in solid-state and nanomaterials science, including functional devices and circuits, assembly, energy conversion and catalysis, and biological sensing. Recommended Course Background: AS.030.301 and AS.030.402 are preferred, but instructor approval may be granted in lieu of these courses.

Distribution Area: Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

**AS.030.404. Electrochemical Systems for Energy Conversion and Storage. 3 Credits.**

This course will be focused on the fundamentals and applications of electrochemical methods in catalysis, charge transport, and energy conversion and storage. Topics that will be covered are basic electrochemical techniques, homogenous and heterogeneous (photo)electrocatalysis, fuel cells, and charge storage devices. The class will conclude with a group report and presentation on a recent development in the field of energy catalysis, conversion, and storage. Course topics include: 1) Fundamentals of electrochemistry, 2) Potential sweep methods and current-controlled techniques, 3) Impedance analysis, 4) Electrochemistry coupled with other characterization methods, 5) Electrocatalysis and photoelectrochemical catalysis, 6) Basics in fuel cells and current technologies (alkaline, polymer exchange membrane, solid oxide...), 7) Basics in batteries and current technologies (Pb acid, Li-based, other metals...) Recommended Course Background: AS.030.204 or AS.030.449 or AS.030.472, or instructor approval for undergraduate students. No pre-requisites for graduate students

Distribution Area: Natural Sciences  
AS Foundational Abilities: Science and Data (FA2)

**AS.030.405. Introduction to Computational Chemistry. 3 Credits.**

This course provides an introduction to the state-of-the-art computational chemistry. The course integrates the basics about molecular electronic structure theories and the corresponding computational aspects and practice in chemical applications. The discussions of theories cover the modern quantum-chemical methods, ranging from mean-field methods (Hartree-Fock method and density-functional theory) to post mean-field methods for treating electron-correlation effects (configuration interaction and coupled cluster). Demonstrative calculations and computer lab practice are designed to deal with the computation of energetic properties (e.g., heat of formation, bond dissociation energy, reaction activation energy, etc) and structural properties (geometry, vibrational frequencies, etc) of representative molecular systems using standard quantum chemistry program package (the Gaussian program, most probably). The class will conclude with a report and presentation on a piece of recent computational work pertinent to the student's research interests.

Distribution Area: Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

**AS.030.406. Teaching Assignment. 3 Credits.**

TA Course for Undergrads

AS Foundational Abilities: Science and Data (FA2)

**AS.030.416. The Chemistry of Transition Metals in Biology. 3 Credits.**

This course will cover fundamental principles in inorganic chemistry, biochemistry, and spectroscopy that are important to the field of bioinorganic chemistry. Current topics in bioinorganic chemistry will be covered, including metalloenzyme structure and function and related synthetic model systems. An emphasis will be placed on the role of transition metals in these systems, and their chemical mechanisms. The collection and interpretation of data from modern bioinorganic spectroscopic tools (e.g. UV-vis, EPR, raman, Mössbauer, X-ray absorption) will be discussed in the context of these current topics.

Distribution Area: Natural Sciences

AS Foundational Abilities: Science and Data (FA2)



**AS.030.417. Metallo(bio)chemistry of Molecular Oxygen. 1.5 Credits.**

This advanced (but descriptive) course focuses on how transition metals of the first row, i.e., iron, manganese and copper), process molecular oxygen (O<sub>2</sub>) in metalloenzymes and coordination complexes. Chemical behavior discussed will be reversible O<sub>2</sub>-binding (e.g., blood dioxygen carriers and their synthetic analogs), insertion of one or both atoms of molecular oxygen into organic substrates (i.e., oxygenase activity), or oxidase (bio)chemistry, wherein the metal ion center facilitates O<sub>2</sub>-reduction to hydrogen peroxide or water. The focus will be on the metal's role and mechanism of action. Practical societal applications will also be discussed.

**Prerequisite(s):** AS.030.449 or equivalent

AS Foundational Abilities: Science and Data (FA2)

**AS.030.421. Data Science Tools for the Chemical and Materials Sciences. 3 Credits.**

Advances in measurement techniques and simulations have driven an explosion in the variety, quality, and quantity of data collected when investigating chemical and materials processes. Advances in computing have led to the practicality of machine learning (ML) and related analytical methods to explore and extract meaning from this cornucopia of data, and data science has been called the fourth pillar of the scientific method. This course will provide an introduction to modern tools of data science, including the Python programming language, Jupyter notebooks, ML algorithms and their practical implementation, and high performance computing, with specific emphasis on applying these tools to data of chemical relevance, including UV/Vis, IR and NMR spectra, 3-D micro computed tomography, and physical property data including specific heat, magnetization, and resistivity.

Distribution Area: Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

**AS.030.424. Molecular Synthetic Biology. 3 Credits.**

Principles and methods for the design and optimization of new biological systems, from a molecular perspective. Topics include: introduction to genetic parts and modern methods for their assembly; synthesis and incorporation of nucleic acids at the level of nucleotides, genes, and genomes; design of genetic programs; library generation and screening; directed evolution and its application to create new proteins and metabolic pathways; computational design of protein and RNA; using physical and bioinformatic approaches; non-canonical amino acids and genetic code expansion. This course will also feature critical evaluation of the primary literature in this fast-paced field, and practical experience with relevant software and computational tools.

**Prerequisite(s):** AS.030.315 OR AS.020.305

Distribution Area: Natural Sciences

AS Foundational Abilities: Writing and Communication (FA1), Science and Data (FA2)

Writing Intensive

**AS.030.441. Spectroscopic Methods of Organic Structure Determination. 3 Credits.**

The course provides fundamental theoretical background for and emphasizes practical application of ultraviolet/visible and infrared spectroscopy, proton and carbon-13 nuclear magnetic resonance and mass spectrometry to the structure proof of organic compounds.

Distribution Area: Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

**AS.030.442. Organometallic Chemistry. 3 Credits.**

An introduction to organometallic chemistry beginning with structure, bonding, and reactivity and continuing into applications to fine chemical synthesis and catalysis. Required Course Background: Organic chemistry-I and -II. Level: Upper level Undergraduate AND Graduate Students

Distribution Area: Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

**AS.030.449. Chemistry of Inorganic Compounds. 3 Credits.**

Physical and chemical properties of inorganic, coordination and organometallic compounds are discussed in terms of molecular orbital, ligand field and crystal field theories. Emphasis on structure and reactivity of these inorganic compounds. Other topics: magnetic properties, electronic spectra, magnetic resonance spectra, reaction kinetics.

Distribution Area: Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

**AS.030.452. Materials & Surface. 3 Credits.**

The chemistry associated with surfaces and interfaces as well as a molecular level understanding of their essential roles in many technological fields. The first half of this course addresses various analytical techniques used to study surfaces including X-ray, photoelectron spectroscopy, and scanning tunneling microscopy. The second half of this course uses a number of case studies to illustrate the application of surface analytical techniques in contemporary research.

Distribution Area: Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

**AS.030.453. Intermediate Quantum Chemistry. 3 Credits.**

The principles of quantum mechanics are developed and applied to chemical problems.

**Prerequisite(s):** AS.030.302

Distribution Area: Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

**AS.030.454. Electrochemistry for Energy Conversion and Storage. 1.5 Credits.**

This half-semester course introduces fundamental concepts in electrochemistry and the application of electrochemical methods for chemical research. The goal of this course is to enable students to practice electrochemistry in laboratory for any field. We will discuss how to use electrochemistry as an analytical technique in your toolbox for understanding chemical reactions as well as the role of electrochemistry in energy conversion and storage.

AS Foundational Abilities: Science and Data (FA2)

**AS.030.456. Chemical Applications of Group Theory. 3 Credits.**

This class will introduce group theory in the chemical/physical context. In addition to the fundamentals of (practical/applied) group theory, this course will explore how the tools of group theory enable powerful, general statements to be made about the behavior of chemical systems from the atomics scale to the macroscale, often without requiring detailed calculations or knowledge of most microscopic details. It is particularly targeted at upper level chemistry and physics undergraduates who have a basic knowledge of quantum mechanics and a brief familiarity with linear algebra.

Distribution Area: Natural Sciences

AS Foundational Abilities: Science and Data (FA2)



**AS.030.501. Independent Research in Physical Chemistry I. 1 - 3 Credits.**

Research under the direction of members of the physical chemistry faculty.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.502. Independent Research in Physical Chemistry. 1 - 3 Credits.**

Research under the direction of members of the physical chemistry faculty.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.503. Independent Research in Inorganic Chemistry I. 1 - 3 Credits.**

Research under the direction of members of the inorganic chemistry faculty.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.504. Independent Research in Inorganic Chemistry. 1 - 3 Credits.**

Research under the direction of members of the inorganic chemistry faculty.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.505. Independent Research in Organic Chemistry I. 1 - 3 Credits.**

Research under the direction of members of the organic chemistry faculty.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.506. Independent Research in Organic Chemistry I. 1 - 3 Credits.**

Research under the direction of members of the organic chemistry faculty.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.507. Independent Research in Biochemistry. 1 - 3 Credits.**

Research under the direction of members of the biochemistry faculty.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.509. Independent Research in Biochemistry II. 1 - 3 Credits.**

Research under the direction of members of the biochemistry faculty.

Recommended Course Background: AS.030.507-AS.030.508 and permission of instructor.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.510. Independent Research in Biochemistry II. 1 - 3 Credits.**

Research under the direction of members of the biochemistry faculty.

Recommended Course Background: AS.030.507-AS.030.508 and permission of instructor.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.511. Independent Research in Materials Chemistry. 1 - 3 Credits.**

Research under the direction of members of the Materials Chemistry faculty.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.512. Independent Research in Materials Chemistry. 1 - 3 Credits.**

Research under the direction of the materials chemistry faculty.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.513. Independent Research in Medical Science. 1 - 3 Credits.**

Research under the direction of members of the medical faculty.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.514. Independent Research in Medical Science. 3 Credits.**

Research under the direction of members of the medical faculty.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)



**AS.030.516. Independent Research in Chemical Biology II. 1 - 3 Credits.**

Research under the direction of Chemical Biology faculty. Permission of instructor required.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.521. Independent Research in Inorganic Chemistry II. 1 - 3 Credits.**

Research under the direction of the inorganic chemistry faculty. Recommended Course Background: AS.030.503-AS.030.504 and permission of instructor.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.522. Independent Research in Inorganic Chemistry II. 1 - 3 Credits.**

Research under the direction of the inorganic chemistry faculty. Recommended Course Background: AS.030.503-AS.030.504 and permission of instructor.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.523. Independent Research in Physical Chemistry II. 1 - 3 Credits.**

Research under the direction of the physical chemistry faculty. Recommended Course Background: AS.030.501-AS.030.502 and permission of instructor.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.525. Independent Research in Organic Chemistry II. 1 - 3 Credits.**

Research under the direction of the organic chemistry faculty. Recommended Course Background: AS.030.505-AS.030.506 and permission of instructor.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.526. Independent Research in Organic Chemistry II. 1 - 3 Credits.**

Research under the direction of members of the Organic Chemistry faculty.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.527. Independent Study. 1 - 3 Credits.**

Research under the direction of the chemistry faculty.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.530. Independent Research in Inorganic and Materials Chemistry. 1 - 3 Credits.**

Research under the direction of members of the Inorganic Chemistry faculty.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.540. Independent Research in Solid State and Materials Chemistry. 1 - 3 Credits.**

Research under the direction of members of the Physical Chemistry faculty.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.593. Research-Organic Chemistry I. 3 Credits.**

Research under the direction of Organic Chemistry faculty members.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.597. Research - Summer. 3 Credits.**

Research under the direction of the chemistry faculty members.

**Prerequisite(s):** You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration, Online Forms.

AS Foundational Abilities: Science and Data (FA2), Projects and Methods (FA6)

**AS.030.601. Statistical Mechanics. 3 Credits.**

An introduction to statistical mechanics of cooperative phenomena using lattice gases and polymers as the main models. Covered topics: phase transitions and critical phenomena, scaling laws, and the use of statistical mechanics to describe time dependent phenomena.

**AS.030.610. Chemical Kinetics. 3 Credits.**

The molecular mechanism of elementary physical and chemical rate processes will be studied. Topics such as elastic scattering, collisional vibrational and rotational energy transfer, chemically reactive collisions, and the theory of unimolecular decay will be covered.

**AS.030.611. Nonadiabatic. 3 Credits.**

Is the chemistry that follows the break down of that sacred cow of low energy chemistry the Born-Oppenheimer approximation. Special attention is paid to the consequences geometric or Berry phase, molecular Aharonov-Bohm effect, the noncrossing rule, ubiquitous conical intersections and their surprising consequences. Examples from the modern literature will be emphasized.



**AS.030.613. Chemistry-Biology Interface Program Forum I. 1 Credit.**

Chemistry-Biology Interface (CBI) program students and faculty will meet weekly in a forum that will host presentations from CBI faculty and students as well as invited guest speakers. These meetings will serve as a valuable opportunity for students to develop presentation skills and interact with CBI students and faculty. Enrollment is required for all CBI students.

**AS.030.614. Chemical-Biology Program Interface Forum II. 1 Credit.**

Chemistry-Biology Interface (CBI) program students and faculty will meet weekly in a forum that will host presentations from CBI faculty and students as well as invited guest speakers. These meetings will serve as a valuable opportunity for students to develop presentation skills and interact with CBI students and faculty. Enrollment is required for first and second year CBI students, and is recommended for advanced year graduate students.

**AS.030.616. The Chemistry of Transition Metals in Biology. 3 Credits.**

This course will cover fundamental principles in inorganic chemistry, biochemistry, and spectroscopy that are important to the field of bioinorganic chemistry. Current topics in bioinorganic chemistry will be covered, including metalloenzyme structure and function and related synthetic model systems. An emphasis will be placed on the role of transition metals in these systems, and their chemical mechanisms. The collection and interpretation of data from modern bioinorganic spectroscopic tools (e.g. UV-vis, EPR, raman, Mössbauer, X-ray absorption) will be discussed in the context of these current topics. Distribution Area: Natural Sciences

**AS.030.617. Metallo(bio)chemistry of Molecular Oxygen. 1.5 Credits.**

This advanced (but descriptive) course focuses on how transition metals of the first row, i.e., iron, manganese and copper, process molecular oxygen (O<sub>2</sub>) in metalloenzymes and coordination complexes. Chemical behavior discussed will be reversible O<sub>2</sub>-binding (e.g., blood dioxygen carriers and their synthetic analogs), insertion of one or both atoms of molecular oxygen into organic substrates (i.e., oxygenase activity), or oxidase (bio)chemistry, wherein the metal ion center facilitates O<sub>2</sub>-reduction to hydrogen peroxide or water. The focus will be on the metal's role and mechanism of action. Practical societal applications will also be discussed.

**AS.030.619. Chemical Biology I. 3 Credits.**

Parts I and II constitute the core course of the Chemistry-Biology Interface (CBI) Program. An introduction to the structure, synthesis, reactivity, and function of biological macromolecules (proteins, nucleic acids, carbohydrates, and lipids) will be provided using the principles of organic and inorganic chemistry. Discussion will incorporate a broad survey of molecular recognition and mechanistic considerations, and introduce the tools of molecular and cellular biology that are utilized in research at the interface of chemistry with biology and medicine. Recommended Course Background: AS.030.206 or equivalent.

**Prerequisite(s):** AS.030.206 or equivalent, and AS.020.305

**AS.030.620. Chemical Biology II. 3 Credits.**

Selected topics of current importance in chemical biology are covered. They include protein engineering and proteomics, cell signaling, protein-nucleic acid interactions (e.g. replication, transcription, DNA repair), catalytic RNA and the ribosome, biosynthesis of natural products, mechanisms of drug action, combinatorial chemistry and chemical genetics, and in vitro selection. Recommended Course Background: AS.030.619 or permission required.

**AS.030.621. Literature-Organic Chemistry. 1 Credit.**

Chemistry graduate students prepare and present their findings based upon approved chemistry literature of their choice.

**AS.030.622. Seminar: Literature of Chemistry. 1 Credit.**

Seminars are presented by advanced graduate students on topics from current chemical journals. Most first-year graduate students are expected to attend for credit. Undergraduates may take the course on a satisfactory/unsatisfactory basis.

**AS.030.623. Molecular Synthetic Biology. 3 Credits.**

Principles and methods for the design and optimization of new biological systems, from a molecular perspective. Topics include: introduction to genetic parts and modern methods for their assembly; synthesis and incorporation of nucleic acids at the level of nucleotides, genes, and genomes; design of genetic programs; library generation and screening; directed evolution and its application to create new proteins and metabolic pathways; computational design of protein and RNA using physical and bioinformatic approaches; non-canonical amino acids and genetic code expansion. This course will also feature critical evaluation of the primary literature in this fast-paced field, and practical experience with relevant software and computational tools.

**AS.030.624. Reading, Writing and Proposing Science. 3 Credits.**

This course will cover practical aspects of preparing a graduate research plan and a personal statement in the format of a predoctoral fellowship. Additionally, skills in literature analysis and oral presentation will be developed along with the art of peer review and productive criticism. Research advisor participation is key to the success of both parts of this course and therefore students should alert their advisors to this activity. Writing Intensive

**AS.030.625. Advanced Mechanistic Organic Chemistry I. 3 Credits.**

The course covers the application of techniques in physical chemistry to the study of organic reaction mechanisms. Topics include chemical bonding and structure, stereochemistry, conformational effects, molecular orbital theory, methods to determine reaction mechanisms, reactive intermediates, and photochemistry. Recommended Course Background: AS.030.205-AS.030.206

**AS.030.626. Advanced Mechanistic Organic Chemistry II. 3 Credits.**

This course covers advanced organic reactions and their mechanisms. Emphasis is given both to methods of postulating mechanisms for rationalizing reaction results and to the use of mechanistic thinking for designing reactions and reagents. This course is intended to be taken in sequence with AS.030.425. Recommended Course Background: AS.030.205-AS.030.206

**AS.030.630. Molecular Photophysics and Photochemistry. 3 Credits.**

This course will introduce fundamental physical, chemical, and analytical concepts underlying light-induced chemical and (molecular-based) material processes. The final weeks of this course will build from these core concepts to survey molecular photoresponses and their consequences or applications in environmental chemistry, chemical biology, and materials science.

Distribution Area: Natural Sciences

**AS.030.640. Light Mediated Chemistry. 3 Credits.**

This course will cover the principles and applications of photochemistry. The principles covered in this course will include the basics of light absorption, understanding atomic and molecular states, and the transitions between these states. Topics of application will include recent advances in photoredox chemistry and other means of photocatalysis. Discussions on techniques to probe these models and mechanisms will also be explored.



**AS.030.648. Biocatalysis: Fundamentals, Recent Advances, and Industrial Applications. 3 Credits.**

Biocatalysis is a rapidly evolving field that adapts biology's mechanisms for innovation to offer revolutionary solutions for chemical production. This course features an in-depth coverage of various topics in biocatalysis with examples of how biocatalysis has reshaped various aspects of modern industries including food manufacturing, pharmaceuticals, consumer products, and biomaterials. This course also provides an overview of common enzyme classes used in bioindustries with extensive discussions of their catalytic mechanisms and engineering. Integrated within the course will be reviewing of important literatures, assessment of critical industrial biocatalytic processes, and hands-on experience of common bioinformatic and computational tools for new enzyme discovery.

**AS.030.652. A Theoretical and Experimental Approach to X-ray Crystallography. 3 Credits.**

The X-ray course will provide a complete approach to X-ray structure to determination (mostly concerned with small molecules) and its uses in Chemistry. The first segment of this course will cover all theoretical aspects of X-ray crystallography, i.e. crystals and crystallization, the nature of X-rays, the diffraction phenomenon of X-rays by crystals, symmetry and space groups, crystal structure analysis. Additionally, the course will provide laboratory experience for the students, involving hands-on instrumentation, experimental methodology to X-ray structure determination, structure solution/refinement, data analyses and publishing data. The course is aimed for graduate students with a strong interest in organic/inorganic chemistry, materials sciences, and physics. Undergraduate students with a major in chemistry are also encouraged to participate.

Distribution Area: Natural Sciences

**AS.030.676. Modern Synthetic Methods in Total Synthesis. 3 Credits.**

An exploration of modern synthetic methods in the context of total synthesis.

**AS.030.677. Advanced Organic Synthesis I. 3 Credits.**

The reactions and principles involved in the synthesis of simple and complex organic compounds. Discussion of famous natural product syntheses and practice in developing rational designs for organic syntheses. Problems in the design of syntheses and in the use of chemical literature.

**AS.030.678. Advanced Organic Synthesis II. 3 Credits.**

Advanced discussion of organic stereochemistry & its application to problems in asymmetric reactions and catalysis will be presented. Emphasis will be placed on the latest reports in the literature, especially with respect to the development of new catalytic, asymmetric processes.

**AS.030.681. Nucleic Acids: Fundamental Chemistry and Applications. 1.5 Credits.**

The course will begin with an overview of nucleic acid structure, synthesis and reactivity. Subsequent topics will include nucleic acid damage & repair, expanding the genetic code, the role of nucleic acids in epigenetics and applications in biotechnology, such as the development of nucleic acid sensors.

**AS.030.800. Summer Independent Research. 9 Credits.**

This course is for active Chemistry PhD students during summer terms

**AS.030.803. CBI Rotations. 3 Credits.**

Open to AS Chemical Biology Interface Graduate Students only

**AS.030.806. Teaching Assignment. 3 Credits.**

TA Course for Grad Students

**AS.030.897. Dissertation Research. 10 - 20 Credits.**

Open to AS Chemistry Graduate Students only.

**Cross Listed Courses****Biophysics****AS.250.310. Exploring Protein Biophysics using Nuclear Magnetic Resonance (NMR) Spectroscopy. 3 Credits.**

NMR is a spectroscopic technique which provides unique, atomic level insights into the inner workings of biomolecules in aqueous solution and solid state. A wide variety of biophysical properties can be studied by solution state NMR, such as the three dimensional structures of biological macromolecules, their dynamical properties in solution, interactions with other molecules and their physical and chemical properties which modulate structure-function relationships (such as electrostatics and redox chemistry). NMR exploits the exquisite sensitivity of magnetic properties of atomic nuclei to their local electronic (and therefore, chemical) environment. As a result, biophysical properties can be studied at atomic resolution, and the global properties of a molecule can be deconstructed in terms of detailed, atomic level information. In addition, interactions between nuclei can be exploited to enhance the information content of NMR spectra via multidimensional (2D and 3D) spectroscopy. Since these properties can be studied in solution, NMR methods serve as an effective complement to X-Ray crystallography and electron microscopy. In this course, we will learn about the basics of NMR spectroscopy, acquire 1D and 2D NMR spectra and use various NMR experiments to characterize and probe biophysical properties of proteins at an atomic level.

**Prerequisite(s):** Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter ASEN in the Search Box to access the proper course. Click here to access the Laboratory Safety Introductory Course (<https://johnshopkins.csod.com/ui/lms-learning-details/app/curriculum/66847e20-c695-4e54-a6be-8c94465b8a70/>);((AS.030.101 AND AS.030.105) OR (AS.030.103 OR AS.030.204)) AND (AS.030.370 OR AS.250.372) AND (AS.020.305 OR AS.030.315 OR AS.250.315) AND AS.030.205 or permission of the instructor.

AS Foundational Abilities: Science and Data (FA2)

**AS.250.315. Biochemistry I. 3 Credits.**

Foundation for advanced classes in Biophysics and other quantitative biological disciplines. This class is the first semester of a two semester course in biochemistry. Topics in Biochemistry I include chemical and physical properties of biomolecules and energetic principles of catabolic pathways.

**Prerequisite(s):** If you have completed AS.250.307 you may not register for AS.250.315.;Students must have completed the following courses to enroll in AS.250.315: AS.030.206 OR AS.030.212

Distribution Area: Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

**AS.250.316. Biochemistry II. 3 Credits.**

Biochemical anabolism, nucleic acid structure, molecular basis of transcription, translation and regulation, signal transduction with an emphasis on physical concepts and chemical mechanisms. Format will include lectures and class discussion of readings from the literature.

**Prerequisite(s):** Students who have taken AS.030.316 are not eligible to take AS.250.316.;( AS.250.315 OR AS.030.315 OR AS.020.305 ) AND ( AS.030.206 OR AS.030.212 ) or permission of the instructor.

AS Foundational Abilities: Writing and Communication (FA1), Science and Data (FA2), Ethics and Foundations (FA5)



**AS.250.372. Biophysical Chemistry. 4 Credits.**

Course covers classical and statistical thermodynamics, spanning from simple to complex systems. Major topics include the first and second law, gases, liquids, chemical mixtures and reactions, partition functions, conformational transitions in peptides and proteins, ligand binding, and allostery. Methods for thermodynamic analysis will be discussed, including calorimetry and spectroscopy. Students will develop and apply different thermodynamic potentials, learn about different types of ensembles and partition functions. Students will learn to use Python and will use it for data fitting and for statistical and mathematical analysis. Background: Calculus and Introductory Physics. Distribution Area: Natural Sciences AS Foundational Abilities: Science and Data (FA2), Ethics and Foundations (FA5)

**Extrdepartmental Studies****PH.550.631. Biological Basis of Public Health. 3 Credits.**

Discusses molecular, biochemical, cellular and immunological methodology and approaches for the mechanistic understanding, treatment and prevention of human diseases, and for understanding disease susceptibility. The focus will be on the application of biological methods and approaches to such critical issues as infectious disease, cancer, neurodegenerative disease, COPD, environmental toxicant effects on early development, and reproductive anomalies and their treatment.

**PH.550.855. MA Public Health Biology Thesis. 5 - 6 Credits.**

Provides an opportunity for students to, in consultation with a faculty mentor from the Dept of Biochem and Molecular Bio, Environmental Health or Molecular Microbiology and Immunology, prepare a critical, scholarly paper on an agreed upon subject area.

**First Year Seminars****AS.001.104. FYS: The Science of Color. 3 Credits.**

This First-Year Seminar is designed to introduce students to the fundamental physical and chemical origins of color and how we perceive them - from the vivid palette provided by the natural world to the brightly colored clothing we wear. Beginning with the basic principles of light and color, we will embark on an interdisciplinary investigation of color, including, but not limited to: color chemistry; color in biology; the physiology of the eye; how color affects human psychology; the history of color and light; and the use of color in art. Discover the physical and chemical explanations behind several noteworthy phenomena such as sunsets, color-blindness, rainbows, fireworks, chameleons and the Aurora Borealis.

**AS.001.105. FYS: The Science Behind the Fiction. 3 Credits.**

In this First-Year Seminar, we will seek to answer questions including: could you forge Beskar? What would it take to make a light saber? Is "Image, enhance" really possible? What is possible today? What might be possible in the future? And, what may never be possible, as it violates the laws of nature as we know them? We will take an empiricist approach, gathering data on the needed properties via screenings and related research, and then applying physical principles to reveal feasibility.

**AS.001.152. FYS: When Chemistry Changed History. 3 Credits.**

The past is littered with discoveries that have altered the course of civilization. In this First-Year Seminar, we will take a deep dive into chemical discoveries that changed history, discussing how they work as well as their impact on society. Topics will range from dirt warfare, to the link between gun powder and workers' rights, to how cats biochemically domesticated humans.

**AS.001.195. FYS: Chemistry and Everyday Living. 3 Credits.**

This First-Year Seminar will delve into the surprising ways that chemistry weaves its way through our day-to-day living. We will discuss topics that cover a variety of useful applications from "Chemistry in Medicine" to "Chemistry in Cooking & Baking". We will explore the material covered in our weekly discussions by carrying out a few experiments to enhance our learning. No prior knowledge of chemistry is required.

**AS.001.257. FYS: Humans, Computers and Artificial Intelligences in Chemistry. 3 Credits.**

In this First-Year Seminar, we will discuss the role of humans, computers, data-aggregators, and large language models in discovering or creating chemical principles - and in how such knowledge is distributed. We will start by discussing the nature of scientific research (e.g. Pasteur's quadrant), and its implications on the funding of science. The results of such work must be published in order for science to be advanced. Should access to it be free (open) to consumers? If not, how is the curation of knowledge to be subsidized? Such dissemination must go beyond scientists, and we will explore ways in which we can communicate science to the public effectively. This will lead us to explore how the information will be synthesized. Whoever can best do this task will undoubtedly make the discoveries of this century. Will it be humans, computers or A.I.? We will explore who might win the 2025 Nobel Prizes in Chemistry and Physics, and whether an A.I. will eventually outperform them.

**Molecular Microbiology and Immunology****PH.260.655. Pandemics of the 20Th Century. 1 Credit.**

Provides students with an overview of protein bioinformatics including computational and experimental approaches. Introduces amino acid and protein physical properties as well as the alignment and evolution of protein sequences. Presents protein structure and methods of structure determination as well as the use of protein databases and software for visualizing proteins and generating publication quality figures. Discusses methods for secondary and tertiary protein structure prediction including homology modeling. Also covers methods for modeling small/molecule-protein interactions within the context of rational drug discovery and design. Finally, introduces students to experimental and computational aspects of mapping protein interaction networks.

**PH.260.844. Causation. 3 Credits.**

Acquaints students with the central concept of causation across the biomedical and public health disciplines. Discusses how cause and effect relationships govern today's research and evidence-based decision-making based on the social, physical, political, and economic determinants of health. Compares how fields and sub-disciplines in biomedicine and public health approach causation using research case examples that illustrate major morbidity and mortality-related health problems. Examines strategies to mitigate the limitations of causal inference.

**Physics & Astronomy****AS.171.671. Advanced Topics in Astrobiology. 3 Credits.**

This is an advanced course discussing mainstream and frontier topics in the five areas of: 1. Cosmology and galaxy, star, black hole and planet formation. 2. Discussions on the astrophysics of (exo-)planets including atmospheres, non-equilibrium atmospheres and biosignatures. 3. Future missions including the Habitable Worlds Observatory. 4. The hazards of space flight and how to overcome them 5. Significant existential questions for life's continuance over the vast timeline of the Universe. Distribution Area: Natural Sciences AS Foundational Abilities: Science and Data (FA2)



For current faculty and contact information go to <http://chemistry.jhu.edu/people/>