

CHEMISTRY

Degree Types: PhD

The Department of Chemistry (<https://www.chemistry.northwestern.edu/graduate/>) focuses on graduate teaching and research at the forefront of the discipline, and prepares students for research positions in industry or academia.

Advanced courses, seminars, and research opportunities are offered in inorganic, organic, physical and biological chemistry. We also promote the interdisciplinary research areas of materials chemistry, environmental chemistry, and the chemistry of life processes.

Our students and faculty collaborate with campus research centers including the Materials Research Science and Engineering Center (MRSEC), the Center for Catalysis and Surface Science, the International Institute for Nanotechnology (IIN), the Argonne-Northwestern Solar Energy Research Center, Chemistry of Life Processes Institute (CLP), Center for Molecular Innovation and Drug Discovery (CMIDD), and the Center for Bio-Inspired Energy Science (CBES).

Additional resources:

- Department website (<https://www.chemistry.northwestern.edu/>)
- Program handbook(s)

Degrees Offered

- Chemistry BA/MS (<https://catalogs.northwestern.edu/tgs/chemistry/chemistry-bach-mast/>)
- Chemistry PhD (<https://catalogs.northwestern.edu/tgs/chemistry/chemistry-phd/>)

Learning objective(s)/Students should be able to...

- Acquire foundational knowledge in advanced chemical topics that provide a basis for development of thesis research projects.
- Students establish clear understanding of their thesis research, show research productivity, and demonstrate the ability to guide further development of their projects.
- Begin to develop independent research ideas.
- Further development of independent research ideas and learning how to construct a compelling proposal.
- Write a compelling research proposal based on an original idea.
- Demonstrate mastery of their research field and the ability to conduct original research.

Chemistry Courses

CHEM 402-0 Principles of Inorganic Chemistry (1 Unit)

Topics in advanced inorganic chemistry. CHEM 302-0 and CHEM 402-0 are taught together.

Prerequisite: CHEM 333-0 or consent of instructor.

CHEM 403-0 Principles of Physical Chemistry (1 Unit)

An overview of advanced topics in physical chemistry. CHEM 303-0 and CHEM 403-0 are taught together.

Prerequisites: CHEM 342-1 and CHEM 342-2 and CHEM 342-3.

CHEM 405-0 Chemistry of Life Processes (1 Unit)

Topics in the chemistry and biochemistry of life processes. Taught with CHEM 305-0.

Prerequisites: full year of organic chemistry and 1 biochemistry course; or consent of instructor.

CHEM 406-0 Environmental Chemistry (1 Unit)

Topics in the physical chemistry of the environment. Taught with CHEM 306-0.

Prerequisites: full year of organic chemistry; background in multivariable integral calculus and differential equations; at least two quarters of general physics; or consent of instructor. BA/MS students must meet the prerequisites of CHEM 306.

CHEM 407-0 Supramolecular Design of Materials and Nanostructures (1 Unit)

Introduction to frontier research at the interface of chemistry and materials science. CHEM 307-0 and CHEM 407-0 are taught together.

Prerequisites: CHEM 215-3 or CHEM 212-3 or 217-3 (C- or better).

CHEM 408-0 Design, Synthesis, and Applications of Nanomaterials (1 Unit)

Approaches to the fabrication, chemical synthesis, assembly and characterization of controlled dimensionality materials including metals, semiconductors, oxides, polymers, and mesoporous scaffolds. Topics include interfacial phenomena and particle stability, nano-forms of carbon, and applications-driven material design. Taught with CHEM 308-0.

CHEM 409-0 Polymer Chemistry (1 Unit)

This course will cover the design and synthesis of polymers, including reaction mechanisms, characterization, and structure-property relationships. CHEM 309-0 is taught with CHEM 409-0. Prerequisites (for undergraduates only): full year of organic chemistry; and one of the following courses: CHEM 307-0/CHEM 407-0, CHEM 313-0/CHEM 413-0, CHEM 319-0/CHEM 419-0, CHEM 412-0, or CHEM 415-0.

CHEM 410-0 Physical Organic Chemistry (1 Unit)

Methods in the investigation of reaction mechanisms. Stereochemistry, conformational analysis, thermochemistry, kinetics, isotope effects, solvent effects, quantitative structure-reactivity relationships, pericyclic reactions, and photochemistry.

CHEM 410-1 Physical Organic Chemistry I (1 Unit)

This course will focus on modern topics in physical organic chemistry, emphasizing the relationship between structure and reactivity. Topics to be covered include molecular orbital theory, orbital symmetry and reactivity, conformational analysis and stereochemistry, stereoelectronic effects, intermolecular forces and solvation, transition state theory, free energy relationships and kinetic isotope effects, and reactive intermediates.

CHEM 410-2 Physical Organic Chemistry II (1 Unit)

This course will focus on modern topics in physical organic chemistry, emphasizing the relationship between structure and reactivity. Topics to be covered include orbital symmetry and reactivity, energy surfaces and Marcus theory, single-electron transfer reactions, solvent effects, nucleophilic and electrophilic reactivity, photochemistry and photocatalysis, organic electronic materials.

CHEM 411-0 Organic Spectroscopy (1 Unit)

Applications of contemporary spectroscopic methods to organic structural and dynamic problems.

CHEM 412-0 Organometallic Reaction Mechanisms (1 Unit)

Organic reaction mechanisms, including carbocations, carbanions, carbenes, nitrenes, radicals, rearrangement reactions and photochemistry.

Prerequisite: full year of organic chemistry or by permission of the instructor.

CHEM 413-0 Advanced Organic Chemistry 1. Advanced concepts of organic reactivity and selectivity in synthesis. (1 Unit)

Advanced topics in organic chemistry: bonding, reaction intermediates, functional group transformations, reaction methodology; approaches to natural product synthesis.

Prerequisite: full year of organic chemistry or by permission of the instructor.

CHEM 414-0 Advanced Organic Chemistry (1 Unit)

Co-listed with CHEM 314-0.

CHEM 415-0 Advanced Organic Chemistry (1 Unit)

Topics vary. Recent topics include carbanions, catalysis of organic reactions, enzyme mechanisms, natural products, nucleotide chemistry, and photochemistry.

CHEM 416-0 Practical Training in Chemical Biology Methods and Experimental Design (1 Unit)

Experimental design, data analysis, mass spectrometry; proteomics, in vivo and molecular imaging, small molecule synthesis and purification; high-throughput screening, x-ray crystallography, analysis of bioelements.

CHEM 419-0 Advanced Organic Synthesis - Concepts and Applications (1 Unit)

Synthesis of natural products and other medicinally relevant organic compounds. Retrosynthetic analysis, substructure keying, and pattern recognition. Classic and modern organic reactions. Terpenes, alkaloids, polyketides, steroids, proteins, and pharmaceuticals.

Prerequisites: CHEM 215-3 or CHEM 212-3 or 217-3 (C- or better).

CHEM 432-0 X-Ray Crystallography (1 Unit)

This class focuses on structure determination by X-Ray Crystallography. The course includes lectures on crystallographic theory and practice as well as hands-on experience with instrumentation and structure determination software.

CHEM 433-0 Structural Inorganic Chemistry (1 Unit)

Chemical applications of group theory and the determination of molecular structure by modern physical techniques.

Prerequisite: previous inorganic chemistry course or by permission of the instructor.

CHEM 434-0 Inorganic Chemistry (1 Unit)

Inorganic and solid-state chemistry of main group elements, particularly those in Group III, second and third transition elements, lanthanides, and actinides.

CHEM 435-0 Advanced Inorganic Chemistry (1 Unit)

Topics vary. Recent topics include organometallic chemistry, coordination chemistry, hydride chemistry, ligand field theory, solid-state chemistry, and photoelectron spectroscopy of inorganic compounds.

CHEM 442-1 Quantum Chemistry (1 Unit)

First Quarter: Principles of basic quantum mechanics, approximation methods, applications to molecules, and introductory group theory. Second Quarter: Molecular orbital theory, applications of group theory, and quantum mechanics as applied to spectroscopy.

CHEM 442-2 Quantum Chemistry (1 Unit)

First Quarter: Principles of basic quantum mechanics, approximation methods, applications to molecules, and introductory group theory. Second Quarter: Molecular orbital theory, applications of group theory, and quantum mechanics as applied to spectroscopy.

CHEM 443-0 Kinetics and Spectroscopy (1 Unit)

The first part of the course focuses on a practical approach to chemical kinetics and dynamics (basic rate laws, rate laws for complex reactions, temperature dependence of reaction rates and their chemical applications). The second part focuses on spectroscopic methods in

solving chemical kinetics and dynamics problems, with fundamental concepts on the interaction of light and matter, the core process in various spectroscopic methods.

CHEM 444-0 Elementary Statistical Mechanics (1 Unit)

Statistical mechanics in chemical systems. Partition functions, thermodynamic correspondence, absolute rate theory, equilibrium, vibration behavior of solids, and adsorption theory.

CHEM 445-0 Advanced Physical & Analytical Chemistry (1 Unit)

Topics vary. Recent topics include electrochemistry, molecular beam kinetics, electron spectroscopy, molecular reaction dynamics, laser spectroscopy, separations, and resonance spectroscopy.

CHEM 448-0 Computational Chemistry (1 Unit)

The theory and application of molecular electronic structure methods, techniques for determining vibrational eigenfunctions and scattering properties, and molecular mechanics, molecular mechanics and Monte Carlo calculations. Included are extensive applications to chemical problems using Unix workstations.

CHEM 460-0 Seminar in Organic Chemistry (0 Unit)

Current research topics presented by visiting and Northwestern University speakers.

CHEM 461-0 Seminar in Physical Chemistry (0 Unit)

Current research topics presented by visiting and Northwestern University speakers.

CHEM 463-0 Seminar in Inorganic Chemistry (0 Unit)

Current research topics presented by visiting and Northwestern University speakers.

CHEM 498-0 Organic Chemistry Independent Study (1 Unit)

Advanced work for students through supervised reading, research, and discussion.

Prerequisite: consent of department.

CHEM 499-0 Independent Study (1 Unit)

May be repeated for credit. Permission of instructor and department required.

CHEM 519-0 Responsible Conduct of Research Training (0 Unit)

The goal of Responsible Conduct of Research (RCR) training is for researchers to perform the most ethical research possible. RCR training is critical to prepare undergraduate students, graduate students, and postdoctoral researchers for ethical challenges that may arise when conducting research. RCR is mandatory for all Department of Chemistry researchers. Undergraduate researchers are required to complete the on-line course only.

CHEM 570-0 Chemistry Colloquium (1 Unit)

N/A.

CHEM 571-0 Research Seminar in Biological Chemistry (1 Unit)

N/A.

CHEM 590-0 Research (1-4 Units)

Independent investigation of selected problems pertaining to thesis or dissertation. May be repeated for credit.