

# CHEMISTRY

Part of the Columbian College of Arts and Sciences, the Chemistry Department has a history that traces back to the very founding of the University. Bridging the sciences of biology, geology, and physics, chemistry is the central science that studies the composition, structure, properties, and behavior of matter at a molecular level. Students and faculty engage in a collaborative setting to address research problems of contemporary importance, focusing on biomolecular chemistry, energy and the environment, and materials chemistry.

## UNDERGRADUATE

### Bachelor's programs

- Bachelor of Arts with a major in chemistry (<http://bulletin.gwu.edu/arts-sciences/chemistry/ba>)
- Bachelor of Science with a major in chemistry (<http://bulletin.gwu.edu/arts-sciences/chemistry/bs>)
- Combined Bachelor of Science with a major in chemistry/ Master of Forensic Sciences with a concentration in forensic chemistry (<http://bulletin.gwu.edu/arts-sciences/chemistry/combined-bs-mfs-forensic-chemistry>)
- Combined Bachelor of Science with a major in chemistry/ Master of Science in the field of environmental and green chemistry (<http://bulletin.gwu.edu/arts-sciences/chemistry/combined-bs-ms-environmental-green-chemistry>)

### Minor

- Minor in chemistry (<http://bulletin.gwu.edu/arts-sciences/chemistry/minor>)

## GRADUATE

### Master's programs

- Master of Science in the field of chemistry (<http://bulletin.gwu.edu/arts-sciences/chemistry/ms>)
- Master of Science in the field of environmental and green chemistry (<http://bulletin.gwu.edu/arts-sciences/chemistry/environmental-green-chemistry-ms>) (<http://bulletin.gwu.edu/arts-sciences/chemistry/ms>)

### Doctoral program

- Doctor of Philosophy in the field of chemistry (<http://bulletin.gwu.edu/arts-sciences/chemistry/phd>)

## FACULTY

**Professors** C.L. Cahill, M. King (Chair), S. Licht, J.H. Miller, A. Vertes

**Associate Professors** C.S. Dowd, M.A. Massiah, V. Sadtchenko, H.H. Teng, M.J. Wagner, M.G. Zysmilich

**Assistant Professors** C. Besson, H. Chen, L.M. McClary, P. Nemes, A.M. Voutchkova

**Professorial Lecturers** E. Libelo

## COURSES

### Explanation of Course Numbers

- Courses in the 1000s are primarily introductory undergraduate courses
- Those in the 2000–4000s are upper-division undergraduate courses that can also be taken for graduate credit with permission and additional work
- Those in the 6000s and 8000s are for master's, doctoral, and professional-level students
- The 6000s are open to advanced undergraduate students with approval of the instructor and the dean or advising office

#### **CHEM 1000. Dean's Seminar. 3 Credits.**

Contemporary topics in chemistry.

#### **CHEM 1003. Contemporary Science for Nonscience Majors. 3 Credits.**

Contemporary topics in physical, biological, and medical science. Chem 1003 is not prerequisite to Chem 1004. Laboratory fee.

#### **CHEM 1004. Contemporary Science for Nonscience Majors. 3 Credits.**

Continuation of CHEM 1003. Contemporary topics in physical, biological, and medical science. Chem 1003 is not prerequisite to Chem 1004. Laboratory fee.

#### **CHEM 1111. General Chemistry I. 4 Credits.**

Atomic structure and properties; stoichiometry; gas, liquid, and solid state; chemical bonding; solutions; chemical kinetics and equilibria; thermodynamics; acids and bases; electrochemistry; descriptive chemistry. Laboratory fee. Restricted to students with one year of high school algebra.

#### **CHEM 1112. General Chemistry II. 4 Credits.**

Continuation of CHEM 1111. Atomic structure and properties; stoichiometry; gas, liquid, and solid state; chemical bonding; solutions; chemical kinetics and equilibria; thermodynamics; acids and bases; electrochemistry; descriptive chemistry. Laboratory fee. Prerequisite: CHEM 1111.

#### **CHEM 2010. History of Chemistry. 2,3 Credits.**

#### **CHEM 2085. Environmental Chemistry. 3 Credits.**

Chemistry and physics of the environment, with emphasis on water and air pollution; environmental analysis and modeling and their limitations.

#### **CHEM 2122. Introductory Quantitative Analysis. 3 Credits.**

Theory and practice of quantitative analysis by modern methods; evaluation of analytical data emphasizing detection and correction of experimental errors. Correlated with CHEM 2123. Prerequisite: CHEM 1112.

**CHEM 2123. Introductory Quantitative Analysis Laboratory. 1 Credit.**

Laboratory complement to CHEM 2122. Prerequisite or concurrent registration: CHEM 2122. Laboratory fee.

**CHEM 2123W. Introductory Quantitative Analysis Laboratory. 1 Credit.**

Laboratory complement to CHEM 2122. Prerequisite or concurrent registration: CHEM 2122. Laboratory fee.

**CHEM 2151. Organic Chemistry I. 3 Credits.**

Systematic treatment of the structure, preparation, properties, and reactions of the principal classes of organic compounds. Fundamental principles of stereochemistry, reaction mechanisms, and spectroscopic methods of analysis. Prerequisite to CHEM 2151: CHEM 1112.

**CHEM 2152. Organic Chemistry II. 3 Credits.**

Continuation of CHEM 2151. Systematic treatment of the structure, preparation, properties, and reactions of the principal classes of organic compounds. Fundamental principles of stereochemistry, reaction mechanisms, and spectroscopic methods of analysis. Prerequisite to CHEM 2152: CHEM 2151.

**CHEM 2153. Organic Chemistry Laboratory I. 1 Credit.**

Laboratory complement of CHEM 2151. Introduction to and practice in basic skills of synthesis, separation, purification, and identification of organic compounds. Prerequisite or concurrent registration: CHEM 2151. Laboratory fee.

**CHEM 2154. Organic Chemistry Laboratory II. 1 Credit.**

Continuation of CHEM 2153. Laboratory complement of CHEM 2152. Introduction to and practice in basic skills of synthesis, separation, purification, and identification of organic compounds. Prerequisite or concurrent registration: CHEM 2152. Prerequisite: CHEM 2153. Laboratory fee.

**CHEM 3140. Geochemistry. 3 Credits.**

Chemical systems and processes on the planet Earth; origins and interactions among and within the Earth's lithosphere, oceans, and atmosphere; origin, distribution, and behavior of the elements; radioactive and stable isotope systems. Aqueous geochemistry; geochemical cycles. Same as GEOL 3140. Prerequisite: GEOL 1001 or GEOL 1005; CHEM 1111-CHEM 1112.

**CHEM 3165. Biochemistry I. 3 Credits.**

Introduction to the chemistry of living cells; structure and function of proteins, lipids, carbohydrates, and nucleic acids; enzyme structure, mechanism, and regulation. Prerequisite: CHEM 2151; credit toward the degree cannot be earned for CHEM 3165 and for BIOC 3261/ BISC 3261.

**CHEM 3166. Biochemistry II. 3 Credits.**

Continuation of CHEM 3165. Introduction to the chemistry of living cells; structure and function of proteins, lipids, carbohydrates, and nucleic acids; enzyme structure, mechanism, and regulation. CHEM 3165 is prerequisite to CHEM 3166. Credit toward the degree cannot be earned for CHEM 3166 and for BIOC 3263/ BISC 3263.

**CHEM 3166W. Biochemistry II. 3 Credits.**

Continuation of CHEM 3165. Introduction to the chemistry of living cells; structure and function of proteins, lipids, carbohydrates, and nucleic acids; enzyme structure, mechanism, and regulation. CHEM 3165 is prerequisite to CHEM 3166. Credit toward the degree cannot be earned for CHEM 3166 and for BIOC 3263/ BISC 3263.

**CHEM 3170. Introduction to Physical Chemistry. 3 Credits.**

Thermodynamics, chemical and physical equilibria, kinetics, and spectroscopy. Examples taken from biological systems. Not open to chemistry majors. May not be taken for credit by students who have received credit for CHEM 3171- CHEM 3172 or an equivalent course. Prerequisites: CHEM 1111- CHEM 1112; MATH 1231; PHYS 1012 or PHYS 1022 or PHYS 1026; or permission of instructor.

**CHEM 3171. Physical Chemistry I. 3 Credits.**

Gas laws, chemical thermodynamics, chemical equilibrium, kinetics, quantum chemistry, atomic and molecular spectra, structure of solids, liquids, and macromolecules. Prerequisite: CHEM 1112; MATH 1231; PHYS 1022; or permission of instructor.

**CHEM 3172. Physical Chemistry II. 3 Credits.**

Continuation of CHEM 3171. Gas laws, chemical thermodynamics, chemical equilibrium, kinetics, quantum chemistry, atomic and molecular spectra, structure of solids, liquids, and macromolecules. Prerequisite: CHEM 3171.

**CHEM 3173. Physical Chemistry Laboratory. 2 Credits.**

Laboratory complement to CHEM 3171 and CHEM 3172. Exploration of molecular structure and bonding as revealed through observation. Laboratory fee. Prerequisites: CHEM 2123 and CHEM 3171; or corequisite: CHEM 2123 and CHEM 3171.

**CHEM 3262. Biochemistry Laboratory. 2 Credits.**

Study of common experimental techniques used in life science laboratories to separate and characterize biological macromolecules. Same as BIOC 3261/ BISC 3261. Prerequisite: CHEM 3165 or BIOC 3261/ BISC 3261. Laboratory fee.

**CHEM 3263W. Special Topics in Biochemistry. 2 Credits.**

**CHEM 3564. Lipid Biotechnology. 0-2 Credits.**

Study of common experimental techniques used in life science laboratories to separate and characterize biological macromolecules. Laboratory fee. Prerequisites: CHEM 3165 or BIOC 3261 or BISC 3261. (Same as BIOC 3564).

**CHEM 4113. Chemical Instrumentation. 3 Credits.**

Electronic analog measurements and control of electrical quantities in chemical instrumentation; digital and analog data conversion and optimization of electronic measurements in chemical instrumentation; computer interfacing and programming using PC-based systems. Prerequisite: CHEM 3172 and CHEM 4122. Laboratory fee.

**CHEM 4122. Instrumental Analytical Chemistry. 3 Credits.**

Theory of instrumental methods in qualitative and quantitative analysis, determination of structure, with emphasis on atomic and molecular spectrophotometry, infrared spectroscopy, nuclear magnetic resonance, mass spectrometry, chromatography, and electroanalysis. Prerequisite or concurrent registration: CHEM 3171 or permission of instructor. Correlated with CHEM 4123.

**CHEM 4123. Instrumental Analytical Chemistry Laboratory. 2 Credits.**

Laboratory complement to CHEM 4122. Prerequisite or concurrent registration: CHEM 3171 and CHEM 4122. Laboratory fee.

**CHEM 4134. Descriptive Inorganic Chemistry. 3 Credits.**

Emphasis on periodic trends and structure and reactivity of transitional metal complexes. Prerequisite: CHEM 2122.

**CHEM 4195. Undergraduate Research. 1-3 Credits.**

Research on problems approved by the staff. Approval must be obtained prior to registration. A final written report on the work is required. For students requesting Special Honors in chemistry, a poster or oral presentation is also required. May be repeated for credit. Majors are encouraged to take the course for two semesters. Laboratory fee.

**CHEM 4195W. Undergraduate Research. 1-3 Credits.**

Research on problems approved by the staff. Approval must be obtained prior to registration. A final written report on the work is required. For students requesting Special Honors in chemistry, a poster or oral presentation is also required. May be repeated for credit. Majors are encouraged to take the course for two semesters. Laboratory fee.

**CHEM 6221. Spectrochemical Analysis. 3 Credits.**

Theory and application of recent spectrometric methods of analysis, including advances in optimization techniques, optical instrumentation, atomic spectrometry, laser-based analytical techniques, X-ray methods, and surface analysis techniques. Prerequisite: CHEM 4122.

**CHEM 6222. Biomedical Mass Spectrometry. 3 Credits.**

Principles, instrumentation, methods, and applications of mass spectrometry; selected state-of-the-art methods demonstrate basic principles to show how new methods of analysis are developed; typical applications highlight solutions of biomedical problems, including proteomics and metabolomics. Prerequisite: CHEM 4122.

**CHEM 6235. Advanced Inorganic Chemistry I. 3 Credits.**

Application of modern chemical theories to inorganic substances and reactions; detailed study, developed from the periodic table, of the chemistry of the more common elements; electronic spectra and reaction mechanisms of complexes; organometallic chemistry; homogeneous and heterogeneous catalysis; bioinorganic chemistry. Prerequisite: CHEM 3172, CHEM 4134.

**CHEM 6236. Advanced Inorganic Chemistry II. 3 Credits.**

Continuation of CHEM 6235. Application of modern chemical theories to inorganic substances and reactions; detailed study, developed from the periodic table, of the chemistry of the more common elements; electronic spectra and reaction mechanisms of complexes; organometallic chemistry; homogeneous and heterogeneous catalysis; bioinorganic chemistry. Prerequisite: CHEM 3172, CHEM 4134.

**CHEM 6238. Chem of Inorganic Materials. 3 Credits.**

Synthesis, structure, and properties of materials such as ceramics, superconductors, ionic conductors, nanomaterials, and magnetic, optical, and electronic materials. Emphasis on traditional and low-temperature routes. Prerequisite: CHEM 3171- CHEM 3172.

**CHEM 6251. Advanced Organic Chemistry I. 3 Credits.**

Synthesis, reactions, and properties of organic compounds; fundamental theories of organic chemistry, emphasis on reaction mechanisms. Prerequisite: CHEM 2152.

**CHEM 6252. Advanced Organic Chemistry II. 3 Credits.**

Continuation of CHEM 6251. Synthesis, reactions, and properties of organic compounds; fundamental theories of organic chemistry, emphasis on reaction mechanisms. Prerequisite: CHEM 6251.

**CHEM 6257. Physical-Organic Chemistry. 3 Credits.**

The transition state theory of chemical kinetics, applications to reaction mechanisms; kinetic isotope effects, linear-free energy relationships, concentrated and "super" acids, Woodward-Hoffman rules, free radical reactions. Prerequisite: CHEM 6251 or permission of instructor.

**CHEM 6259. Polymer Chemistry. 3 Credits.**

A study of the preparation, properties, and structure of macromolecules. Prerequisite: CHEM 2152 and CHEM 3170 or CHEM 3171 or permission of instructor.

**CHEM 6273. Chemical Thermodynamics. 3 Credits.**

Application of thermodynamics to chemical problems. Emphasis on statistical calculation of thermodynamic properties. Prerequisite: CHEM 3172 or CHEM 6372.

**CHEM 6277. Chemical Bonding. 3 Credits.**

Quantum mechanics, approximate methods, electron spin, Pauli principle, atomic and molecular structure. Prerequisite: CHEM 3172 or CHEM 6372.

**CHEM 6278. Molecular Spectroscopy. 3 Credits.**

Applications of quantum mechanics and group theory to the interpretation of electronic, vibrational, rotational, and magnetic resonance spectroscopy. Prerequisite: CHEM 6277.

**CHEM 6280. Energy and the Environment. 3 Credits.**

Fundamentals of energy conversion in thermomechanical, thermochemical, electrochemical, and photoelectric processes in existing and future power and transportation systems, with emphasis on efficiency, environmental impact, and performance.

**CHEM 6281. Environmental Chemistry: Air, Water, and Soil. 3 Credits.**

Survey of the behavior, movement and impact of natural and man-made chemicals in all layers of the environment in the context of the atmosphere, hydrosphere, and lithosphere; the effects of acid rain, sewage treatment, ozone destruction, anthropogenic climate change, air pollution, and eutrophication.

**CHEM 6282. Green Industrial Chemistry. 3 Credits.**

Introduction to the basic design principles for greener chemical technologies; widely used practices, including catalysis, use of renewable starting materials, minimization of energy inputs, and use of greener solvents.

**CHEM 6283. Chemical Toxicology and Rational Design of Safer Chemicals. 3 Credits.**

Introduction to the basic tools and paradigms of toxicology in the context of chemical design for minimizing potential toxicity of commercial chemicals; computational methods for prediction of bioavailability, reactivity, bioaccumulation and different types of toxicity; application of in silico methods to the rational re-design of functional and safer chemicals.

**CHEM 6284. Environmental Analytical Chemistry. 3 Credits.**

Advanced analytical methodology for environmental assessment; analytical instrumentation, techniques for remote measurements, determination of trace atmospheric constituents of anthropogenic and natural origin, measurement uncertainty analysis, detection and identification of organic and inorganic pollutants in air, water, soil and biota, and the determination of heavy metals and radionuclides in the environment.

**CHEM 6298. Capstone Seminar in Environmental and Green Chemistry. 3 Credits.**

Group projects carried out with an external partner or client—such as a government agency, nonprofit group, or chemistry laboratory research project—that identify and solve real world scientific problems related to environmental and green chemistry.

**CHEM 6314. Fundamental-Computational Chem. 3 Credits.**

**CHEM 6315. Computational Chem-Biomolecule. 3 Credits.**

**CHEM 6320. Selected Topics in Analytical Chemistry. 1-3 Credits.**

Advanced topics offered in a modular format to allow an in-depth examination of a self-selected field of analytical chemistry. One to three topics may be chosen for a given semester. May be repeated for credit.

**CHEM 6330. Selected Topics in Inorganic Chemistry. 1-3 Credits.**

Advanced topics offered in a modular format to allow an in-depth examination of a self-selected field of inorganic chemistry. One to three topics may be chosen for a given semester. May be repeated for credit.

**CHEM 6350. Selected Topics in Organic Chemistry. 1-3 Credits.**

Advanced topics offered in a modular format to allow an in-depth examination of a self-selected field in organic chemistry. One to three topics may be chosen for a given semester. May be repeated for credit.

**CHEM 6358. Synthesis and Structure Determination in Organic Chemistry. 3 Credits.**

The design of syntheses for complex organic molecules; survey of modern synthetic methods, including asymmetric induction; spectroscopic methods of structure determination. Prerequisite: CHEM 6251 or permission of instructor.

**CHEM 6370. Selected Topics in Physical Chemistry. 1-3 Credits.**

Advanced topics offered in a modular format to allow an in-depth examination of a self-selected field of physical chemistry. One to three topics may be chosen for a given semester. May be repeated for credit.

**CHEM 6371. Physical Chemistry I. 1-3 Credits.**

Gas laws, chemical thermodynamics, chemical equilibrium, kinetics, quantum chemistry, atomic and molecular spectra, structure of solids, liquids, and macromolecules. Students enrolled at the graduate level are expected to do additional work. Restricted to students with departmental approval.

**CHEM 6372. Physical Chemistry II. 1-3 Credits.**

Continuation of CHEM 6371. Basic concepts of quantum chemistry and molecular spectroscopy; application of modern physical chemistry theory to exploration of a wide range of physical properties for open and closed chemical systems in the gas and condensed phases. Restricted to students with departmental permission. Prerequisite: CHEM 6371. (Same as CHEM 3172).

**CHEM 6390. Selected Topics in Chemistry. 0-3 Credits.**

Advanced topics offered in a modular format to allow an in-depth examination of a self-selected field in chemistry. One to three topics may be chosen for a given semester. May be repeated for credit.

**CHEM 6395. Research. 1-12 Credits.**

Limited to master's degree candidates. Survey of a topic approved by departmental staff and resulting in a written report and presentation of a seminar. Open to qualified students with advanced training. May be repeated for credit.

**CHEM 6998. Thesis Research. 1-9 Credits.**

Limited to students in the master's degree program.

**CHEM 6999. Thesis Research. 3 Credits.**

Limited to students in the Master's Degree program.

**CHEM 8998. Advanced Reading and Research. 1-12 Credits.**

Limited to students preparing for the Doctor of Philosophy general examination. May be repeated for credit.

**CHEM 8999. Dissertation Research. 3-12 Credits.**

Limited to Doctor of Philosophy candidates. May be repeated for credit.