Chemistry (CHEM)

Faculty

Professors: Charles H. Clapp, David Rovnyak, George C. Shields (Dean, College of Arts and Sciences), Robert A. Stockland, Timothy G. Strein, Eric S. Tillman, Brian W. Williams

Associate Professors: Dee Ann Casteel (Chair), Karen J. Castle, Molly M. McGuire, James S. Swan

Assistant Professors: William D. Kerber, Michael R. Krout, Rebecca L. Switzer

Visiting Assistant Professors: Dabrina Dutcher, Paul Kennedy

Laboratory Directors: Patrick Martino, Erica Merriett (organic chemistry), Neluni Perera (general analytical)

GC/MS Specialist: Peter M. Findeis

Computer, Instrument and NMR Specialist: Brian Breczinski

Chemistry is the science that seeks to understand the structure and composition of matter and the changes that it undergoes. The atomic/molecular perspective of chemistry provides fundamental insight into the macroscopic world of materials and organisms. Chemists apply this insight in many ways, such as the synthesis of new substances with useful technological or therapeutic properties and the discovery of new analytical methods that can be used in medicine and environmental science. Coursework in chemistry seeks to acquaint students with fundamental chemical principles, teach students to apply these principles broadly and effectively, and enable students to evaluate critically the impact of chemistry on society.

In addition to providing a working knowledge of chemical principles, a major in chemistry offers experience in critical thinking, data analysis and experimental design. Chemistry graduates pursue a variety of careers in which these skills are important. Many work as chemists in chemical or pharmaceutical companies or in government labs. Others apply their chemical skills to careers in medicine, law, business, chemical or pharmaceutical sales, biotechnology, pharmacology, toxicology or environmental science. Many chemistry graduates pursue careers in education at the secondary, college or university level.

The department emphasizes the importance of research experience. The opportunity to engage in an original research investigation, in collaboration with a faculty member, is a distinctive feature of this program.

The chemistry major may be pursued under either the Bachelor of Arts or the Bachelor of Science degree programs. Students interested in biochemistry should consider either the Bachelor of Science in chemistry curriculum with biochemistry and biology electives or the Bachelor of Science program in cell biology/biochemistry offered jointly by the chemistry and biology departments.

Bachelor of Arts Major

A **Bachelor of Arts major** consists of eight course credits in chemistry numbered 211 or above, five of which are required:

Required Courses		
CHEM 211	Organic Chemistry I	1
CHEM 212	Organic Chemistry II	1
CHEM 221	Inorganic Chemistry I [1]	1
or CHEM 222	Accelerated General Chemistry: Inorganic	
CHEM 231	Analytical Chemistry	1
CHEM 340	Biological Physical Chemistry	1
or CHEM 341	Physical Chemistry I	
MATH 201	Calculus I [2]	1
PHYS 211	Classical and Modern Physics [3]	1
Electives		
3 CHEM courses numbered 211 or above [4]		3

1 CHEM 222 Accelerated General Chemistry: Inorganic by permission

2 MATH 202 Calculus II is strongly recommended.

3 PHYS 212 Classical and Modern Physics is strongly recommended.

4 A maximum of one course credit of CHEM 375 Undergraduate Research or CHEM 376 Undergraduate Research can count toward the eight course credit requirement.

Bachelor of Science Major

A **Bachelor of Science major** consists of 10 course credits in chemistry numbered 211 or above, eight of which are required:

Required Courses		
CHEM 211	Organic Chemistry I	1
CHEM 212	Organic Chemistry II	1
CHEM 221	Inorganic Chemistry I [5]	1
or CHEM 222	Accelerated General Chemistry: Inorganic	
CHEM 231	Analytical Chemistry	1
CHEM 322	Inorganic Chemistry II	1
CHEM 332	Analytical Chemistry II	1
CHEM 341	Physical Chemistry I	1
CHEM 342	Physical Chemistry II	1
MATH 201	Calculus I	1
MATH 202	Calculus II	1
MATH 211	Calculus III	1
PHYS 211	Classical and Modern Physics I	1
PHYS 212	Classical and Modern Physics II	1
PHYS 235	Applied Electronics	1
Science elective		1
Electives		
2 CHEM courses numbered 211 or above		2

[5] CHEM 222 Accelerated General Chemistry: Inorganic by permission

The sequence of chemistry courses indicated below is strongly recommended; exceptions to this sequence are rare, and each must be negotiated with the student's adviser on the merits of the particular case.

The recommended sequence for the Bachelor of Science major is as follows:

First Year			
First Semester	**Credits**	**Second Semester**	**Credits**
CHEM 211	1	CHEM 212	1
MATH 201	1	MATH 202	1
	2		**2**
Sophomore			
First Semester	**Credits**	**Second Semester**	**Credits**
CHEM 221	1	CHEM 231	1
MATH 211	1	PHYS 212	1
PHYS 211	1		
	3		**2**
Junior			
First Semester	**Credits**	**Second Semester**	**Credits**
CHEM 341	1	CHEM 322	1
Science elective (see table below)	1	CHEM 342	1
		PHYS 235[6]	1
	2		**3**
Senior			
First Semester	**Credits**	**Second Semester**	**Credits**
CHEM 332	1	Elective in chemistry	1
Elective in chemistry	1		
	2		**1**

Total Credits: 17

6 ECEG 205 Electrical and Computer Engineering Fundamentals may be substituted for PHYS 235 Applied Electronics in either semester.

Science Electives

BIOL 205	Introduction to Molecules and Cells	1
CHEG 450	Polymer Science	1
CSCI 203	Introduction to Computer Science I	1
GEOL 305	Introduction to Geochemistry	1
MATH 212	Differential Equations	1
PHYS 310	Experimental Physics	1
PHYS 317	Thermodynamics and Statistical Mechanics	1
PHYS 332	Quantum Mechanics	1
PHYS 333	Electromagnetic Theory I	1
Other courses with department approval		1

Electives in chemistry during the senior year may be chosen from any of the 300-level undergraduate courses in chemistry.

No more than two credits of research, CHEM 375 Undergraduate Research or CHEM 376 Undergraduate Research , may be applied toward the minimum 10-course major.

Advanced placement credit accepted by the University will count as a credit toward graduation, but will not replace the number of chemistry courses above 211 that are required for a major in chemistry.

Transfer students who are given at least 1.5 transfer credits toward graduation based on two semesters of general chemistry taken prior to transfer will be given an adjustment such that those two courses will replace the specific requirement for CHEM 221 Inorganic Chemistry I and will count as one of the chemistry courses required for the chemistry degree.

Bachelor of Science graduates will not automatically achieve the American Chemical Society's certification. To fulfill these requirements, Bachelor of Science chemistry students should take the equivalent of at least two additional laboratory or research courses, and CHEM 351 Biochemistry I.

Of the 11 electives to be taken during the four undergraduate years, an additional mathematics course is desirable. Since science is an international enterprise, chemistry majors are encouraged to take a foreign language.

Students interested in coordinating graduate with undergraduate work should consult the department chair before the end of the sophomore year. The department offers a combined B.S./M.S. program for students who desire both more research and more advanced chemistry courses than are obtainable under the Bachelor of Science program. The B.S./M.S. program normally is elected in the sophomore year and is completed in the summer following the senior year.

Satisfying Disciplinary Depth Component of the College Core Curriculum

Culminating Experience

Chemistry majors (B.S. and B.A.) will meet the Culminating Experience requirement in one of the following ways.

- Carry out a research or independent study project in the chemical sciences and take CHEM 371 Chemistry Lecture Series, a 0.25-credit research seminar in the senior year. Each student enrolled in the research seminar will give a formal presentation on the research or independent study project that s/he has undertaken. The research or independent study component can be any one of the following:
  a. at least one credit of undergraduate research (CHEM 375 Undergraduate Research or CHEM 376 Undergraduate Research),
  b. a summer research project carried out either at Bucknell or elsewhere (research projects carried out elsewhere must have prior approval by the department),
  c. an independent study project that involves some form of scholarly work in the chemical sciences other than a laboratory research project.
- Take, during the senior year, one of the 0.5-credit special topics seminar courses (CHEM 385 Seminar or CHEM 386 Seminar) that the department offers. These seminars apply principles that students have learned in their core chemistry courses to topics of current interest, and require each student to give a formal presentation.

Writing Within the Major

All chemistry majors are required to take either CHEM 340 Biological Physical Chemistry or CHEM 341 Physical Chemistry I which offer instruction in scientific writing and require students to write formal lab reports. The writing requirement can also be satisfied with CHEM 322 Inorganic Chemistry II, CHEM 332 Analytical Chemistry II, or CHEM 342 Physical Chemistry II.

Formal Presentation Experience

Each of the ways in which B.A. and B.S. chemistry majors can satisfy the Culminating Experience requirement will require formal presentation(s) under the guidance of the research mentor or seminar course instructor.

Information Literacy

Any 0.5 or 1.0 credit chemistry course at the 300 level will satisfy this requirement.

Two **minors** are available in the department of chemistry:

Chemistry Minor

The minor in chemistry requires six chemistry course credits.

Select one of the following: [1]		1
CHEM 160	Introduction to Environmental Chemistry	
CHEM 201	General Chemistry	
CHEM 202	General Chemistry	
CHEM 221	Inorganic Chemistry I	
CHEM 222	Accelerated General Chemistry: Inorganic	
AP chemistry credit		
Chemistry courses numbered higher than 211, including:		5
CHEM 375	Undergraduate Research [2]	
CHEM 376	Undergraduate Research [2]	

1 Not required. No more than one course may count toward the minor.

2 A maximum of one course credit may be applied toward a chemistry minor.

Biochemistry Minor

The chemistry (biochemistry) minor requires:

Required Courses		
CHEM 351	Biochemistry I	1
CHEM 352	Biochemistry II	1
Electives		
4 CHEM courses numbered 211 or above [3]		4

3 A maximum of one course credit in research (CHEM 375/376) may be applied toward a biochemistry minor.

Learning Outcomes for Undergraduate Chemistry Majors

(Mapped to Bucknell University Education Goals)

Students will:

1. demonstrate proficiency in the traditional core areas of chemistry (organic, inorganic, analytical, and physical). (1, 4, 6, 9)
2. demonstrate proficiency in at least one specialty area of chemistry and/or chemical research. (1, 4, 6, 8, 9)
3. demonstrate the ability to apply quantitative or qualitative theories of molecular behavior to chemical problems. (1, 4, 6, 9)
4. perform analytical and/or synthetic procedures and demonstrate the ability to critically evaluate the results. (1, 4, 6)
5. find, retrieve, and evaluate information from the chemical literature and use it properly. (1, 4, 6, 8)
6. write well-organized and scientifically accurate laboratory and/or research reports. (7)
7. effectively communicate scientific information through oral presentation. (7)

Courses

CHEM 105. Introduction to Chemistry. 1 Credit.
Offered Fall Semester Only; Lecture hours:3,Lab:3
A terminal elementary course covering in-depth selected topics, which may vary from year to year. Satisfies science requirement for Bachelor of Arts students not majoring in science or engineering. Not open to students who have taken CHEM 160. Prerequisite: seniors by permission only.

CHEM 160. Introduction to Environmental Chemistry. 1 Credit.
Offered Spring Semester Only; Lecture hours:3,Lab:3
One semester terminal course in chemistry. Introduction to the basic chemistry principles that govern natural processes and anthropogenic effects on the environment. Satisfies laboratory science requirement for Bachelor of Arts students not majoring in science or engineering.

CHEM 201. General Chemistry I. 1 Credit.
Offered Fall Semester Only; Lecture hours:3,Other:5
Fundamental principles in inorganic chemistry. Atomic structure, bonding, equilibrium, kinetics, etc. Laboratory experiments are both qualitative and quantitative. Credit not given for both CHEM 201 and CHEM 221.

CHEM 202. General Chemistry II. 1 Credit.
Offered Spring Semester Only; Lecture hours:3,Other:4
Fundamental principles in inorganic chemistry. Atomic structure, bonding, equilibrium, kinetics, etc. Laboratory experiments are both qualitative and quantitative. CHEM 201 is a prerequisite for CHEM 202. Credit not given for CHEM 202 and CHEM 221 or CHEM 231.

CHEM 211. Organic Chemistry I. 1 Credit.
Offered Fall Semester Only; Lecture hours:4,Other:5
First-year, first-semester course for students majoring in chemistry, biochemistry, and biology. Bonding and structure in organic compounds, resonance, organic acid/base reactions, basic nomenclature, conformational analysis, stereochemistry, properties and reactions of functional groups. Prerequisite: high school chemistry or equivalent.

CHEM 212. Organic Chemistry II. 1 Credit.
Offered Spring Semester Only; Lecture hours:4,Other:5
A continuation of CHEM 211 with focus on properties and reactions of functional groups, synthesis, and spectroscopic analysis. Prerequisite: CHEM 211.

CHEM 221. Inorganic Chemistry I. 1 Credit.
Offered Fall Semester Only; Lecture hours:2,Other:4
Introduction to structures, bonding theories, and reactivity of inorganic systems. Introductory thermodynamics and kinetics. Emphasizes hands-on, experiential learning in workshops and laboratory. Prerequisite: CHEM 212 or permission of the instructor.

CHEM 222. Accelerated General Chemistry: Inorganic. 1 Credit.
Offered Spring Semester Only; Lecture hours:3,Other:5
Atomic structure and introductory quantum mechanics. Molecular structure and theories of bonding. Introductory thermodynamics and kinetics. Introduction to coordination chemistry. Laboratory: introduction to quantitative techniques. Prerequisite: Chemical Engineering students. All others by permission of the instructor.

CHEM 231. Analytical Chemistry. 1 Credit.
Offered Spring Semester Only; Lecture hours:3,Other:5
Chemical equilibrium and modern analysis with an emphasis on acid-base systems, solubility, metal ion determinations, electroanalytical chemistry, spectrophotometry, and separation methods. Prerequisite: CHEM 221 or CHEM 222.

CHEM 2NT. Chemistry Non-traditional Study. 1-2 Credits.
Offered Fall, Spring, Summer; Lecture hours:Varies,Other:Varies
Non-traditional study in chemistry. Prerequisite: permission of the instructor.

CHEM 304. X-ray Crystallography. .5-1 Credits.
Offered Either Fall or Spring; Lecture hours:Varies,Other:Varies
Independent Study. Symmetry (point, plane, and space groups) diffraction (reciprocal space, precession photographs, automated data collection) and structural solution (Patterson Maps, Electron Density Maps, Refinement). Prerequisite: permission of the instructor.

CHEM 313. Synthetic Organic Chemistry. 1 Credit.
Offered Either Fall or Spring; Lecture hours:3,Recitation:1
Modern synthetic organic chemistry, with examples involving complex natural products. Application of organic mechanism, synthetic strategy, and advanced transformations to total synthesis. Prerequisite: CHEM 212. Crosslisted as CHEM 613.

CHEM 314. Mechanistic Organic Chemistry. 1 Credit.
Offered Either Fall or Spring; Lecture hours:4,Recitation:2
Thermal and kinetic aspects of organic reactions are discussed along with the effect of substituents, solvents, and stereochemistry on reaction pathways. Qualitative molecular orbital theory of organic compounds is covered in depth. Weekly problem sessions are held. Prerequisites: CHEM 211 and CHEM 212. Crosslisted as CHEM 614.

CHEM 317. Special Topics in Organic Chemistry. 1 Credit.
Offered Either Fall or Spring; Lecture hours:4; Repeatable
Available by independent study. Prerequisites: CHEM 212 and permission of the instructor.

CHEM 322. Inorganic Chemistry II. 1 Credit.
Offered Spring Semester Only; Lecture hours:3,Lab:4
Survey course in modern inorganic chemistry covering transition metal, coordination, organometallic, and bioinorganic chemistry. Laboratory will consist of synthetic and physical measurements as well as the manipulation of air sensitive materials. Prerequisite: CHEM 231. Crosslisted as CHEM 622.

CHEM 327. Special Topics in Inorganic Chemistry. 1 Credit.
Offered Either Fall or Spring; Lecture hours:4; Repeatable
Topics vary. Available by independent study. Prerequisite: CHEM 221. Crosslisted as CHEM 627.

CHEM 332. Analytical Chemistry II. 1 Credit.
Offered Fall Semester Only; Lecture hours:3,Lab:4
Theory and practice of techniques of instrumental analysis including spectrophotometry, fluorescence, mass spectrometry, atomic absorption, chromatography, capillary electrophoresis, and dynamic electrochemistry. Prerequisite: CHEM 231. Crosslisted as CHEM 632.

CHEM 337. Special Topics in Analytical Chemistry. 1 Credit.
Offered Either Fall or Spring; Lecture hours:4
Available by independent study. Prerequisite: CHEM 231 and permission of the instructor. Crosslisted as CHEM 637.

CHEM 340. Biological Physical Chemistry. 1 Credit.
Offered Spring Semester Only; Lecture hours:3,Other:6
Introduction to physical chemistry for life science students, with emphasis on thermodynamics, hydrodynamics and spectroscopy. Not open to B.S. chemistry majors. Prerequisites: CHEM 231, MATH 201, and PHYS 211. MATH 202 and PHYS 212 are recommended. Crosslisted as CHEM 640.

CHEM 341. Physical Chemistry I. 1 Credit.
Offered Fall Semester Only; Lecture hours:3,Other:5
Introductory physical chemistry with emphasis on thermodynamics, kinetics and electrochemistry. Prerequisites: CHEM 231, MATH 211, and PHYS 212. Not open to engineering majors. Crosslisted as CHEM 641.

CHEM 342. Physical Chemistry II. 1 Credit.
Offered Spring Semester Only; Lecture hours:3,Other:5
Introductory physical chemistry with emphasis on quantum mechanics, structure and bonding, molecular spectroscopy and statistical mechanics. The customized laboratory experience will emphasize applications of spectroscopy and computational methods. Prerequisite: CHEM 341. Crosslisted as CHEM 642.

CHEM 343. Physical Chemistry for Engineers. 1 Credit.
Offered Fall Semester Only; Lecture hours:3,Recitation:1
Introductory physical chemistry for engineers, with emphasis on thermodynamics, chemical kinetics and electrochemistry. Prerequisites: CHEM 231, MATH 211, PHYS 211. Only open to engineering majors.

CHEM 347. Special Topics in Physical Chemistry. 1 Credit.
Offered Either Fall or Spring; Lecture hours:4
Available by independent study. Prerequisites: CHEM 231 and permission of the instructor. Crosslisted as CHEM 647.

CHEM 351. Biochemistry I. 1 Credit.
Offered Fall Semester Only; Lecture hours:4,Recitation:1
Introduction to biological chemistry with emphasis on the structure and function of proteins, lipids, carbohydrates and nucleic acids, kinetics and mechanisms of enzymes, bioenergetics, and metabolism. Prerequisites: CHEM 212 and either CHEM 231 or CHEM 202. Crosslisted as CHEM 651.

CHEM 352. Biochemistry II. 1 Credit.
Offered Spring Semester Only; Lecture hours:4,Recitation:1
Advanced topics in protein structure and function, protein folding, enzyme mechanisms, electron transport and free-energy coupling mechanisms, biosynthesis, metabolic regulation, and supramolecular assemblies. Prerequisite: CHEM 351 or permission of the instructor. Crosslisted as CHEM 652.

CHEM 357. Special Topics In Biochemistry. 1 Credit.
Offered Either Fall or Spring; Lecture hours:3,Other:1
Structure/function relationships and dynamics of biomolecules. Prerequisite: permission of the instructor.

CHEM 358. Biochemical Methods. 1 Credit.
Offered Spring Semester Only; Lecture hours:2,Other:6
A course in laboratory techniques including cell fractionation, protein, and nucleic acid analysis. Spectrophotometry, chromatography, centrifugation, electrophoresis, and mass spectrometry are emphasized. Prerequisites: BIOL 205 and CHEM 351 and permission of the instructor. Crosslisted as BIOL 340.

CHEM 360. Advanced Environmental Chemistry. 1 Credit.
Offered Fall Semester Only; Lecture hours:4
Chemistry of the atmosphere, hydrosphere, and lithosphere. Natural processes and anthropogenic effects will be discussed. Prerequisite: CHEM 231 or permission of the instructor. Crosslisted as CHEM 660.

CHEM 371. Chemistry Lecture Series. .25 Credits.
Offered Both Fall and Spring; Lecture hours:1; Repeatable
Formal oral presentations on current research will be given by students, faculty and visiting scientists. Prerequisites: participation in an approved research project or independent study for seniors or second term juniors only.

CHEM 375. Undergraduate Research. .5-2 Credits.
Offered Both Fall and Spring; Lecture hours:Varies,Other:Varies; Repeatable
Original investigations in analytical, biological, organic, physical, environmental or inorganic chemistry.

CHEM 376. Undergraduate Research. .5-2 Credits.
Offered Both Fall and Spring; Lecture hours:Varies,Other:Varies; Repeatable
Original investigations in analytical, biological, organic, physical, environmental or inorganic chemistry.

CHEM 385. Seminar. .5 Credits.
Offered Both Fall and Spring; Lecture hours:2; Repeatable
Topics vary. Crosslisted as CHEM 685.

CHEM 386. Seminar. .5 Credits.
Offered Both Fall and Spring; Lecture hours:2; Repeatable
Topics vary. Crosslisted as CHEM 686.