CHEMISTRY

Overview and Contact Information
Chemistry is the study of the composition, synthesis, physical properties, and transformations of materials, including biological substances, technological materials, and natural products. The goals of the chemistry major are to give students a firm foundation in the fundamental principles of chemistry, its subdisciplines, and their interrelationships; to develop a proficiency in experimental technique, design, and interpretation; and to expose students to contemporary research questions and applications. This is accomplished through hands-on experience with modern instrumentation throughout the curriculum, a broad array of advanced coursework, and engagement in active discussion and collaboration with the chemistry faculty.

See Also
• Biochemistry (http://catalog.mtholyoke.edu/areas-study/biochemistry/)
• Engineering (http://catalog.mtholyoke.edu/areas-study/engineering/)
• Dual-Degree in Engineering (http://catalog.mtholyoke.edu/other-programs/other-degree-certificate-programs/)

Contact Information
Kathryn McMenimen, Chair
Dina Bevivino, Academic Department Coordinator
G04 Carr Laboratory
413-538-2214
https://www.mtholyoke.edu/academics/find-your-program/chemistry

Learning Goals
Knowledge-Based Learning Goals
• Understand the physical basis and utility of hierarchical representations of structure (atomic, molecular, macro/supramolecular) at appropriate levels of sophistication.
• Understand the physical basis and utility of spectroscopic and analytical technologies.
• Use energy, kinetics, and thermodynamics to develop a quantitative and mechanistic view of chemical systems.
• Apply structural and energetic models to describing and predicting the functions and interactions of molecules.
• Apply chemical knowledge to socially significant endeavors.

Skill-Based Learning Goals
• Solve chemical problems using both qualitative and quantitative methods.
• Design and conduct independent experiments in chemistry, using modern instrumentation.
• Interpret and critically analyze data.
• Critically evaluate primary scientific literature.
• Effectively communicate scientific information in oral, written, and visual formats to scientific and broader audiences.
• Collaborate to pursue common goals.

• Employ responsible and ethical practices in data collection and analysis, documentation, reporting, and attribution.
• Assess safety concerns in the laboratory and employ best practices.

Faculty
This area of study is administered by the Department of Chemistry:
Wei Chen, Marilyn Dawson Sarles, M.D. Professor of Life Sciences and Professor of Chemistry
Maria Gomez, Elizabeth Page Greenawalt Professor of Chemistry, Teaching Fall Only
Darren Hamilton, Bertha Phillips Rodger Professor of Chemistry, Teaching Spring Only
Katie Berry, Associate Professor of Biochemistry
Kyle Broaders, Associate Professor of Chemistry
Donald Cotter, Associate Professor of Chemistry, Teaching Fall Only
Kathryn McMenimen, Associate Professor of Chemistry
Alan Van Giessen, Associate Professor of Chemistry
Jonathan Ashby, Assistant Professor of Chemistry

Requirements for the Major
A minimum of 48 credits:

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<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>CHEM-150</td>
<td>General Chemistry: Foundations of Structure and Reactivity</td>
<td>4</td>
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<tr>
<td>or CHEM-160</td>
<td>Integrated Introduction to Biology and Chemistry</td>
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<tr>
<td>CHEM-202</td>
<td>Organic Chemistry I (^1)</td>
<td>4</td>
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<tr>
<td>CHEM-231</td>
<td>Inorganic Chemistry (^1)</td>
<td>4</td>
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<tr>
<td>CHEM-302</td>
<td>Organic Chemistry II</td>
<td>4</td>
</tr>
<tr>
<td>CHEM-306</td>
<td>Analytical Chemistry (^1)</td>
<td>4</td>
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<tr>
<td>or CHEM-223</td>
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<tr>
<td>CHEM-308</td>
<td>Chemical Thermodynamics with Lab</td>
<td>4</td>
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<tr>
<td>8 additional credits in Chemistry at the 300 level (^2)</td>
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One of the following courses in biological or macromolecular science:

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<tr>
<td>CHEM-309</td>
<td>Introduction to Materials</td>
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<tr>
<td>CHEM-312</td>
<td>Chemistry of Biomolecules</td>
</tr>
<tr>
<td>CHEM-317</td>
<td>Principles of Polymer Chemistry</td>
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Mathematics (also needed as prerequisites for certain courses above)

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<tr>
<th>Code</th>
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<tbody>
<tr>
<td>MATH-101</td>
<td>Calculus I</td>
<td>4</td>
</tr>
<tr>
<td>MATH-102</td>
<td>Calculus II</td>
<td>4</td>
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<tr>
<td>MATH-203</td>
<td>Calculus III</td>
<td>4</td>
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Total Credits 48

\(^1\) These may be taken in any order after CHEM-150 (or CHEM-160)
\(^2\) PHYS-205, Introduction to Mathematical Methods for Scientists, can be counted as a chemistry elective
**Other Requirements**

- Senior Symposium. An individual oral presentation at the annual Senior Symposium for those seniors taking CHEM-395.

**Additional Specifications**

- Additional recommendations for students considering graduate work:
  - PHYS-110 and PHYS-201
  - In-depth courses in at least four sub-disciplines
  - MATH-211 or PHYS-205

- Additional requirements for ACS certification:
  - PHYS-110 and PHYS-201
  - A course in biological chemistry, for example CHEM-312
  - A course in polymer or material science, for example CHEM-317
  - At least four in-depth courses (i.e. 300-level)
  - At least one semester of independent research (i.e. CHEM-295 or CHEM-395)
  - A total of 400 laboratory hours at the 200 level and above, including up to 180 hours of independent research

- For advising purposes, a typical Plan of Study (p. ), showing a recommended sequence of course-taking to complete the major is provided.

- Independent work is encouraged and usually takes the form of work on a problem allied to the research interests of a faculty member, details of which are available from the chemistry department office and website (https://www.mtholyoke.edu/acad/chemistry/).

A number of Mount Holyoke College students participate in the department’s summer research program (eight to ten weeks of paid, full-time research), a valuable addition to their education. Students may pursue independent work at any time in their Mount Holyoke careers. The department is extremely well equipped for research, including one high-field nuclear magnetic resonance (NMR) spectrometer, two atomic force microscopes (AFM), several gas (GC) and high performance liquid (HPLC) chromatographs, numerous infrared (IR), ultra-violet/visible (UV-Vis) and fluorescence spectrometers (XRF), in addition to specialized equipment for microwave promoted synthesis of peptides and organic molecules, calorimetry, dynamic light scattering, optical microscopy, electrochemistry and computational molecular modeling.

**ACS Certification of an Undergraduate Degree in Chemistry**

The Department of Chemistry is approved by the American Chemical Society. The Committee on Professional Training of the American Chemical Society sets the criteria for approval of a chemistry program; the chair of the approved program certifies annually those students who have met the curricular guidelines.

**Requirements for the Minor**

A minimum of 16 credits:

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<td></td>
<td>At least 12 credits in chemistry at the 200 level or above</td>
<td>12</td>
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<td></td>
<td>At least 4 credits in chemistry at the 300 level</td>
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Total Credits 16

Students interested in pursuing licensure in the field of chemistry can combine their course work in chemistry with a minor in education.

In some instances course work in the major coincides with course work required for licensure; in other cases, it does not. For specific course requirements for licensure within the major of chemistry, please consult your advisor or the chair of the chemistry department. See further information in the catalog about the minor in education (http://catalog.mtholyoke.edu/areas-study/psychology-education/#minortext) and Teacher Licensure (http://catalog.mtholyoke.edu/areas-study/psychology-education/#teacherlicensure#textcontainer) and consult Ms. Lawrence in the psychology and education department.

Licensure requires a formal application as well as passing scores on the Massachusetts Test of Educator Licensure (MTEL) in both the literacy component and the subject matter component. Copies of the test objectives for the MTEL are available in the chemistry department and in the Department of Psychology and Education.

Additional information about the Licensure Program, including application materials, can be found on the Teacher Licensure Program website (https://www.mtholyoke.edu/academics/find-your-program/teacher-licensure/).

**Course Advice**

**Selecting Chemistry Courses**

All students regardless of background preparation are required to begin their study of chemistry with either CHEM-150 General Chemistry: Foundations of Structure and Reactivity or CHEM-160 Integrated Introduction to Biology and Chemistry (must be taken concurrently with BIOL-160).

- CHEM-150 focuses in the fundamental concepts in chemistry and how they affect the structure and reactivity of molecules. This course covers the electronic structure of atoms and molecules, chemical bonding, molecular shape, functional groups, stoichiometry, chemical reactivity and equilibrium. CHEM-150 is offered in both Fall and Spring semesters.

- CHEM-160, taken concurrently with BIOL-160, is intended for students with an interest in biochemistry, neuroscience, and the health professions. This course covers similar material to CHEM-150 but emphasizes the connections between chemistry and biology and features a single lab section for both courses. Offered only in the Fall semester.

**Course Offerings**

**CHEM-150 General Chemistry: Foundations of Structure and Reactivity**

*Fall and Spring. Credits: 4*

This course provides an introduction to the fundamental concepts of chemistry, including the electronic structure of atoms and molecules, chemical bonding, molecular shape, functional groups, stoichiometry, chemical reactivity and equilibrium. The laboratory emphasizes basic skills, quantitative chemical measurements, and principles discussed in lectures.

*Applies to requirement(s): Math Sciences*  
J. Ashby, A. van Giessen  
Coreq: CHEM-150L.  
Notes: This course is offered in both fall and spring semesters.
CHEM-160 Integrated Introduction to Biology and Chemistry
Fall. Credits: 4
This 8-credit course serves as a gateway to both the biology and chemistry core curricula. The course introduces and develops fundamental concepts in chemistry while also exploring the diverse range of strategies adopted by living systems to survive in different environments. This course prepares students for further study in chemistry and/or biology (Biology 200). Students must register for both Biology 160 and Chemistry 160 as well as a single lab section (listed under Chemistry 160). Recommended for students interested in completing pre-health requirements or advanced study in biochemistry or neuroscience.
Applies to requirement(s): Math Sciences
W. Chen
Restrictions: This course is limited to first-year students.
Coreq: BIOL-160 and CHEM-160L.
Notes: Students must co-enroll in Biology 160 and Chemistry 160 for a total of 8 credits; three 50 minute lectures, three 75 minute lectures, and one three-hour laboratory per week.

CHEM-199 Introduction to Research
Spring. Credits: 4
This seminar is for first-year students who have a strong interest in the chemical sciences and will help to prepare them for scientific research. Students will be exposed to various research topics through reading, discussing, presenting, and writing about primary literature and attending selected department seminars. Throughout the semester students will carry out one research-style project in order to gain experience with the multifaceted nature of scientific inquiry. To jump start their research career on campus, each student will arrange meetings with at least two science faculty followed by a presentation and a written description on the faculty members’ research topics.
Applies to requirement(s): Meets No Distribution Requirement
K. Berry
Restrictions: This course is limited to first-year students.
Instructor permission required.
Prereq: CHEM-150 or CHEM-160.
Advisory: Interested students should complete the online application.

CHEM-202 Organic Chemistry I
Fall and Spring. Credits: 4
This course introduces the core principles of the language of organic chemistry and extends their use to the description of the behavior and reactivity of carbonyl containing functional groups. Topics include representation and naming, the use of various spectroscopic approaches to probe molecular structure, an overview of bonding models and molecular geometry, the development of mechanistic drawing, and the application of this mechanistic approach to the reactions of a wide range of carbonyl compounds. The accompanying laboratory course introduces a range of essential analytical, preparative and purification techniques, provides practice in the interpretation of spectroscopic data, and culminates with the preparation of organic materials related to the lecture course.
Applies to requirement(s): Math Sciences
K. Broaders, K. McMenimen
Prereq: CHEM-150, or CHEM-160, or CHEM-101 and CHEM-201. Coreq: CHEM-202L.
CHEM-302 Organic Chemistry II
Fall. Credits: 4
This course provides a direct continuation of Organic Chemistry I (CHEM-202) and develops and extends many of the concepts and approaches developed therein. Topics include stereochemistry, substitution and elimination reactions, conformational analysis, addition reactions of multiple bonds, substitution reactions of aromatic systems, and a broad extension of the carbonyl chemistry introduced in the preceding class. Consideration will be given to the development of organic syntheses of specific materials and attendant issues of compatibility and selectivity in reaction choice. The scope and reach of the spectroscopic methods introduced in Organic Chemistry I will be extended and applied to structure determination. Laboratory work will include the preparation, isolation and purification of a wide range of organic materials of relevance to the lecture course.
Applies to requirement(s): Math Sciences
K. Broaders
Prereq: CHEM-202 with grade of C or better. Coreq: CHEM-302L.

CHEM-306 Analytical Chemistry
Fall. Credits: 4
This course serves as an introduction to quantitative analytical chemistry, with a combined emphasis on both classical analysis tools and commonly used instrumental techniques. Topics to be covered include figures of merit, statistical and error analysis, titrimetric and gravimetric analysis, and sample preparation techniques. Instrumental methods covered will include atomic/molecular spectroscopy, chromatography and mass spectrometry. In the laboratory, students will apply techniques covered in lecture to quantitation of analytes commonly seen in pharmaceutical, forensic, chemical and biological settings, and will also learn the fundamentals of method development and optimization.
Applies to requirement(s): Math Sciences
Other Attribute(s): Speaking-Intensive, Writing-Intensive
J. Ashby
Prereq: CHEM-231 and 4 credits in Mathematics. Coreq: CHEM-306L.

CHEM-308 Chemical Thermodynamics with Lab
Fall. Credits: 4
A consideration of the contribution of thermodynamics to the understanding of the 'driving forces' for physical chemical changes and the nature of the equilibrium state. Topics will include statistical mechanics, thermodynamics, and kinetics.
Applies to requirement(s): Math Sciences
M. Gomez
Prereq: MATH-203 or PHYS 205, and CHEM-223 or CHEM-231, all with grade of C or better. Coreq: CHEM-308L.

CHEM-309 Introduction to Materials
Not Scheduled for This Year. Credits: 4
This integrated lecture/lab course provides an introduction to different types of materials, including metals, ceramics, polymers, and composites, emphasizing structure and property relationships. The principles behind the design and implementation of materials as well as advances in materials in the areas of nano-, bio-, and electronic technology will be presented. Class time is split among lecture, discussion, and laboratory.
Applies to requirement(s): Math Sciences
W. Chen
Prereq: CHEM-201 or CHEM-231, CHEM-202, and MATH-101

CHEM-311 Protein Biochemistry and Cellular Metabolism
Fall. Credits: 4
This course is a rigorous introduction to the study of protein molecules and their role as catalysts of the cell. Topics include general principles of protein folding, protein structure-function correlation, enzyme kinetics and mechanism, carbohydrate and lipid biochemistry, and metabolic pathways (catabolic and anabolic) and their interaction and cross-regulation. Biological transformation of energy is considered in light of the principle of thermodynamics.
Crosslisted as: BIOCH-311
Applies to requirement(s): Math Sciences
K. Berry
Restrictions: This course is limited to Biochemistry majors only.

CHEM-312 Chemistry of Biomolecules
Fall. Credits: 4
An examination of the major ideas of biochemistry from the point of view of the chemical sciences rather than the life sciences. The focus will be on structure and reactivity of important biomolecules and the role of energetics and reaction dynamics in biochemical processes. Major metabolic pathways are covered, including those of proteins, carbohydrates, lipids, and nucleic acids.
Crosslisted as: BIOCH-312
Applies to requirement(s): Math Sciences
K. Berry
Prereq: CHEM-202 with a grade of C or better.
Advisory: This course is NOT intended for biochemistry majors, who must take BIOCH-311 and BIOCH-314. CHEM-312 students may take BIOCH-318 concurrently.

CHEM-314 Nucleic Acids Biochemistry and Molecular Biology
Spring. Credits: 4
This course is an in-depth examination of DNA and RNA structures and how these structures support their respective functions during replication, transcription, and translation of the genetic material. Emphasis is on the detailed mechanisms associated with each step of gene expression. Discussions incorporate many recent advances brought about by recombinant DNA technology.
Crosslisted as: BIOCH-314
Applies to requirement(s): Math Sciences
K. Berry
Restrictions: This course is limited to Biochemistry majors only.
Prereq: BIOCH-311. Coreq: CHEM-314L.
Advisory: CHEM-302 can be taken concurrently

CHEM-314WT Nucleic Acids Biochemistry and Molecular Biology
Not Scheduled for This Year. Credits: 4
This course is an in-depth examination of DNA and RNA structures and how these structures support their respective functions during replication, transcription, and translation of the genetic material. Emphasis is on the detailed mechanisms associated with each step of gene expression. Discussions incorporate many recent advances brought about by recombinant DNA technology.
Applies to requirement(s): Math Sciences
K. Berry
Restrictions: This course is limited to Biochemistry majors only.
Prereq: BIOCH-311.
CHEM-317 Principles of Polymer Chemistry
Not Scheduled for This Year. Credits: 4
An introduction to the study of molecules of high molecular weights with emphasis on synthetic rather than naturally occurring polymers. Topics include polymer syntheses, structures, and characterization.
Applies to requirement(s): Math Sciences
W. Chen
Prereq: CHEM-302.

CHEM-321 Forensic Chemistry
Not Scheduled for This Year. Credits: 4
Forensic chemists apply their knowledge of analytical chemistry to the identification of trace unknowns present in a crime scene. In this course, the function of chemical instrumentation such as chromatography, spectroscopy, and microscopy will be discussed. In addition, we will investigate how this instrumentation can be used for the analysis of various types of physical evidence, such as inks, fibers, drugs, and arson/explosion evidence. Finally, this course will also serve as a brief introduction to pharmacokinetics, as well as an introduction to concepts within forensic science such as expert testimony and quality assurance of forensic analysis.
Applies to requirement(s): Math Sciences
Other Attribute(s): Speaking-Intensive
J. Ashby
Prereq: CHEM-202 and CHEM-223.

CHEM-325 Atomic and Molecular Structure with Lab
Spring. Credits: 4
This course is an introduction to experimental and theoretical approaches to the determination of the structure of atoms, molecules, and chemical bonds. Classroom work provides background in the theory of atomic and molecular structure and an introduction to quantum mechanics and spectroscopy.
Applies to requirement(s): Math Sciences
A. van Giessen
Prereq: MATH-203 or PHYS-205, and CHEM-223 or CHEM-231, all with grade of C or better. Coreq: CHEM-325L.
Advisory: MATH-203 is recommended.

CHEM-326 Poisons: Death by Chemistry
Not Scheduled for This Year. Credits: 4
This course uses a Problem-Based Learning approach to look at the effect of poisons at the molecular, cellular, and physiological levels from the chemistry and biochemistry perspective. We'll discuss: the classification of poisons and the common structural elements of the molecules within each class; the interaction of toxic molecules with proteins and nucleic acids present in the cell; the physiologic effect of toxins on different systems of the body; dosage effects and pharmacokinetics; the mechanisms by which antidotes work; and the analytical techniques that toxicologists use to determine which poisons are present in the body. The different classes of poisons will be discussed in the context of historical case studies.
Applies to requirement(s): Math Sciences
A. van Giessen
Prereq: Any 200-level Chemistry course.
Advisory: Students who have taken CHEM-226 may not enroll in CHEM-326.

CHEM-329 Cosmetic Chemistry
Not Scheduled for This Year. Credits: 4
This course will introduce the chemistry, formulation, and physical characteristics of personal care products. The topics will include basic skin physiology, hygiene products, adornment products for face, nail, and hair, as well as current trends and advances in cosmetic dermatology. An integral part of the course will involve hands-on experience in making and characterizing some common skincare and cosmetic products.
Applies to requirement(s): Math Sciences
W. Chen
Prereq: CHEM-302.

CHEM-330 Advanced Topics in Chemistry
CHEM-330RN Advanced Topics in Chemistry: 'The RNA World: The Origin of Life to Modern Cells'
Not Scheduled for This Year. Credits: 4
RNA is believed by many to have been the first macromolecule to evolve. In a hypothesized "RNA world," RNA would have simultaneously served the roles of carrying genetic information and catalyzing chemical reactions within early cells. The past three decades have been a renaissance for RNA biology, as researchers have uncovered the critical role RNA plays in eukaryotic and bacterial gene regulation and defense, as well as the potential for RNAs to perform catalysis. This seminar will introduce students to modern approaches to study the structure and function of RNA and will explore the chemical and biological roles RNA plays in modern cells as well as its role in the origin of life.
Crosslisted as: BIOCH-330RN
Applies to requirement(s): Math Sciences
Other Attribute(s): Speaking-Intensive
K. Berry
Prereq: BIOCH-311, or BIOCH-314, or CHEM-312.

CHEM-334 Advanced Inorganic Chemistry
Not Scheduled for This Year. Credits: 4
The implications of molecular symmetry as expressed in the language of group theory are explored in some depth. Group theory provides the context for a discussion of the structural and spectroscopic properties of inorganic compounds, particularly those of the transition metals. Topics include molecular orbital theory, vibrational spectroscopy, and electronic spectroscopy.
Applies to requirement(s): Math Sciences
D. Cotter
Prereq: CHEM-231.

CHEM-336 Organic Synthesis
Not Scheduled for This Year. Credits: 4
This course emphasizes recent developments in synthetic organic chemistry and deals with general synthetic methods and specific examples of natural product synthesis. It covers such topics as new methods of oxidation and reduction, stereospecific olefin formation, ring-forming reactions, and methods of carbon-carbon bond formation. The application of these reactions to the synthesis of naturally occurring compounds is examined. A general strategy for the synthesis of complex molecules is also presented.
Applies to requirement(s): Math Sciences
K. Broaders
Prereq: CHEM-302.
**CHEM-339 The Organic Chemistry of Biological Pathways**  
*Spring. Credits: 4*
This course explores the underlying organic chemistry of biological pathways and thereby seeks to build a framework for understanding biological transformations from the perspective of mechanistic organic chemistry. Beginning with common biological mechanisms, and drawing parallels with their sophomore organic chemistry counterparts, a broad overview will be constructed of the pathways by which the key classes of biological molecules—lipids, carbohydrates, amino acids, nucleotides—are manufactured, modified, and consumed. Several specific biosyntheses will also be dissected from a mechanistic perspective. These case studies will include antibiotics, an alkaloid, and heme.  
*Applies to requirement(s): Math Sciences*
D. Hamilton  
*Instructor permission required.*  
*Prereq: CHEM-302.*

**CHEM-346 Physical Chemistry of Biochemical Systems With Lab**  
*Spring. Credits: 4*
This course provides an overview of the fundamental principles of physical chemistry with an emphasis on their application to the study of biological molecules and processes. Topics will include statistical mechanics, thermodynamics and enzyme kinetics. Discussion of applications will relate commonly used experimental techniques—such as spectroscopy and calorimetry—to the fundamental principles on which they are based. In addition, students will gain experience and confidence in the use of mathematical models to describe biochemical systems.  
*Applies to requirement(s): Math Sciences*
A. van Giessen  
*Restrictions: This course is limited to Biochemistry majors only.*  
*Prereq: MATH-203 or PHYS-205, and CHEM-223 or CHEM-231, all with a grade of C or better. Coreq: CHEM-346L.*

**CHEM-348 Using Data Science to Find Hidden Chemical Rules**  
*Fall. Credits: 4*
Chemists have always been interested in understanding patterns in their data. The scientific method uses observations to create theories and models to understand physical phenomena. Data science algorithms allow us to find unexpected patterns in chemical data. New chemical theories can be developed using a combination of data from either experiment or simulation, algorithms and physical insight. This class uses the case method providing three challenge problems to find hidden chemical rules from large chemical data sets through algorithms and physical insight. There will be lectures on the physical/chemical problems, the data sets, and the possible algorithms to consider before the teams of students tackle these problems. The teams will write papers on their findings and use the peer review process to improve their papers.  
*Applies to requirement(s): Math Sciences*
*Other Attribute(s): Writing-Intensive*
M. Gomez  
*Prereq: MATH-102 and either any chemistry or any computer science class.*

**CHEM-349 Food Chemistry: the Science of the Kitchen**  
*Fall. Credits: 4*
Food Chemistry is an integrated lecture/lab course that focuses on the molecular bases of chemical phenomena that dictate the behavior of foods. We will examine topics such as trans fats, baking soda as a leavening agent in baking, the chemical basis for ripening of fruit, pectin as a cellular glue, artificial sweeteners, GMOs, and enzymatic and non-enzymatic browning of foods. The emphasis is on the major food components (water, lipids, proteins, and carbohydrates) and their behavior under various conditions. Content will be discussed using a variety of contexts including primary scientific literature, mainstream media, and food blogs. Laboratories provide opportunities for students to observe, manipulate, and explore topics in food chemistry under conditions of particular relevance to food processing.  
*Applies to requirement(s): Math Sciences*
K. McMenimen  
*Prereq: CHEM-302 with a grade of C or better.*

**CHEM-395 Independent Study**  
*Fall and Spring. Credits: 1 - 8*
The department  
*Instructor permission required.*  
*Notes: See safety training restrictions in description of Chemistry 295*